Orthodontics in 3 millennia. Chapter 8: The cephalometer takes its place in the orthodontic armamentarium

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After World War II, cephalometric radiography came into widespread use, enabling orthodontists to measure changes in tooth and jaw positions produced by growth and treatment. Cephalometrics revealed that many malocclusions resulted from faulty jaw relationships, not just malposed teeth, and made it possible to see that jaw growth could be altered by orthodontic treatment. Since 1931, a multitude of analyses have been developed, whereby the face is inscribed in triangles, rectangles, and polygons, permitting the orthodontist to dissect the profile into an array of angular and distance measurements. Those who embraced too quickly these measurements as a panacea soon learned that they are best taken with a grain of good judgment. (Am J Orthod Dentofacial Orthop 2006;129:574-80)

Only 6 years after the publication of Brodie's 1941 thesis (see Chapter 7), Arne Björk[1] (1911-96; Swedish) (Fig 1) published his own doctoral dissertation, *The Face in Profile*, for the Swedish Institute of Human Genetics (1947), showing that, contrary to Brodie's findings, jaw growth does not proceed in a linear, translatory fashion. He contended that the mandible becomes more prognathic with age, which is associated with a decrease in the angulation of the lower border as well as a decrease in the angle of convexity. In 1955 he conducted the first human growth study using implants, discovering greater rotation of the maxilla and mandible.

Form-function relationship

Robert E. Moyers[2] (1919-96) (Fig 2) was the most highly decorated dental officer in the history of the US Army. During World War II, he parachuted behind enemy lines in Greece to serve as an OSS officer and participate in the resistance movement in German-occupied territory. After the war he traded his overseas cap for a mortarboard, obtaining a PhD from the University of Iowa in 1949. The University of Toronto was already waiting for him to become the founding chair of their orthodontic department, the first such program in Canada. However, most of his research was done as chairman of the Department of Orthodontics at the University of Michigan and later as director of the Center for Human Growth and Development.

He spent a lifetime in clinical research, providing a better understanding of the role of the neuromusculature in normal facial growth as well as during clinical treatment. His leadership of a National Institutes of Health-funded program in craniofacial growth and development led to a broader understanding of the form-function relationship in the craniofacial region.[3]

Laminagraphy

There was hardly an area of orthodontics that, at one time or another, Robert M. Ricketts (1920-2003) (Fig 3) was not involved in—although he had a shaky start. Brodie nearly expelled him from the Illinois graduate program for his writing ineptitude. But in an early manifestation of his determination, he went on to become one of orthodontics' most prolific writers—and doers.

The first of his many encounters with controversy occurred when Ricketts questioned his mentor's assertion that the rest position was constant, arguing for a changing rest position and challenging Brodie's finding of the constancy of the whole growth pattern (telephone interview, Robert M. Ricketts, December 19, 1994). Even before completing his graduate studies, Ricketts opened the TMJ for direct investigation in the living with his pioneering work in laminagraphy (body section radiography).[4]

His other scientific interests were in the fields of bone growth, morphological variation of the face and jaws, arthritis of the jaw joint, cleft palate treatment,

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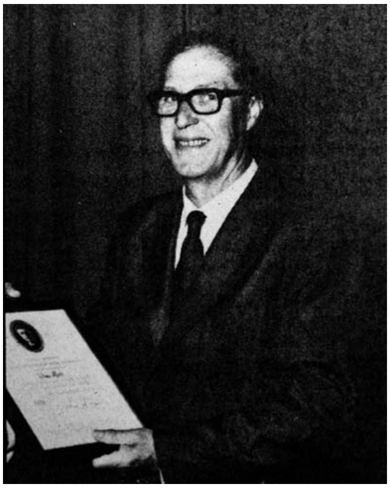

Fig 1. Arne Björk achieved world fame for his *Face in Profile.*

Fig 2. Research efforts of Robert E. Moyers led to better understanding of neuromusculature in form-function relationship.

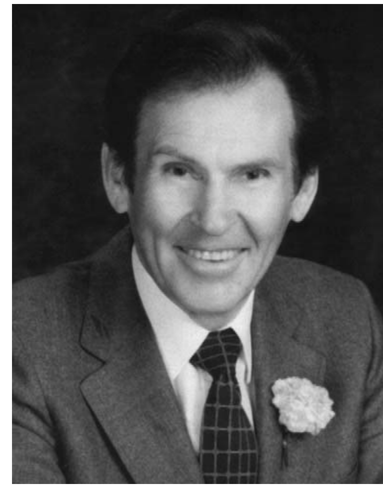

Fig 3. Robert M. Ricketts was innovator, free thinker, and true renaissance man.

Fig 4. Coenraad F. A. Moorrees made Forsyth Dental Center midcentury mecca for study of child growth.

cephalometrics, computerization, psychology, rehabilitative mechanics, and treatment effects. In the field of craniofacial growth, Ricketts:

- Developed the first cephalometric analysis that allowed clinicians to compare their patients with norms based on age, sex, and race (Ricketts analysis).
- Developed the first cephalometric diagnostic system to project treatment plus growth in treatment planning–the visualized treatment objective (VTO).
- Developed a computer-generated method for projecting growth to maturity using the mandibular archial growth (long-range forecasting) method.
- Developed computer-driven cephalometric diagnostics (Rocky Mountain Data Systems).
- Was the first in recent history to expound in detail on the divine proportion and the Fibonacci series in the treatment of dental and skeletal problems.[5]

Individual growth

Coenraad F. A. Moorrees[6] (1916-2003) (Fig 4) was Holland's gift to American orthodontics. Although he received his dental training at Penn (1941), he was called to duty in World War II by the Dutch government. After an almost 3-year imprisonment by the Japanese, he became affiliated with the Forsyth Dental Infirmary in Boston and began a long research career in child growth and dental anthropology.

Moorrees' interest in the growth of the individual as opposed to the average child led to the finding that children often pass through seemingly abnormal stages before reaching the end of puberty with acceptable occlusions. His research of the Aleut population under the aegis of anthropologist Earnest A. Hooton (1887-1954) led to *The Aleut Dentition* (1957), a comprehensive study of tooth morphology, emergence, occlusion, and dental diseases.

His use of natural head position was an innovative approach that has demonstrated biologic variations in many craniofacial landmarks. His classic volume, *The Dentition of the Growing Child* (1959) is the product of a most comprehensive longitudinal study of the dentition of children aged 3 to 18.

CEPHALOMETRICS

Cephalometric radiography, which came into widespread use after the Second World War, enabled orthodontists to measure the changes in tooth and jaw positions produced by growth and treatment. Among other findings, these radiographs revealed that many Class II and Class III malocclusions resulted from faulty jaw relationships, not just malposed teeth. By the use of cephalometrics, it was also possible to see that jaw growth could be altered by orthodontic treatment.[7]

According to Salzmann,[8] roentgenographic cephalometrics can:

- Show dimensional relationship of the craniofacial components.
- Reveal manifestations of growth and developmental abnormalities.
- Aid in treatment planning.
- Help analyze changes obtained.
- Assist in evaluating the effectiveness of different orthodontic treatment procedures.
- Show dentofacial growth changes after treatment is completed.

The goal of cephalometric analysis is to estimate the relationship, vertically and horizontally, of the jaws to the cranial base and to each other, the relationships of the teeth to their supporting bone, and the effect of the teeth on the profile. Orthodontists further use this technology to evaluate the structures' proportions and to identify possible causes for malocclusions.[9] Analysis of growth and alteration of growth could also be evaluated by taking serial radiographs and comparing them with each other, that is, before and after treatment. After the invention of cephalometric radiography, Lucien de Coster of Belgium was the first (1939) to publish an analysis based on proportional relationships in the face conforming to principles used in antiquity.

Fig 5. Concept of relating mandibular incisor to lower border of mandible stems from investigations of Herbert I. Margolis (right, with Joe D. Peak).

Maxillofacial triangle

In the United States, systematized clinical analyses were somewhat slower in being formulated. Herbert I. Margolis (1900-84) (Fig 5), a Ukrainian by birth, was the first to relate the mandibular incisor to the lower border of mandible (1943), leading to the Tweed Triangle. His cephalometric investigations stemmed from contact with Hooton, combining anatomy with evolution. Margolis developed the facial line (nasion-pogonion) and maxillofacial triangle, which adheres to the concept of individual variation, and designed the Margolis cephalostat.[10]

Anteroposterior dysplasia

Wendell L. Wylie[11] (1913-66), noted educator, administrator, researcher, and speaker, developed an analysis based on dividing dimensions along the Frankfort plane into contributing linear components. "Dysplasia" implies a random combination of craniofacial parts that might be neither abnormally large nor small, but, when taken together, produce an undesirable combination of parts.

Downs analysis

William B. Downs[12] (1899-1966) (Fig 6) was a member of Brodie's first class (1930) at Illinois and became a mainstay of the teaching staff. With Brodie, Goldstein, and Myer, he coauthored "Cephalometric Appraisal of Orthodontic Results" (1938). In 1947, he completed a landmark study, "Variations in Facial

Fig 6. William B. Downs came up with first cephalometric analysis that had clinical application.

Fig 7. Richard A. Riedel was still a student when he introduced widely accepted ANB angle.

Relationships: Their Significance in Treatment and Prognosis," which came to be known as the Downs analysis. Its twofold purpose was to appraise the pattern of the facial skeleton exclusive of the teeth and the relationship of the teeth and alveolar processes to the facial skeleton. It was the first cephalometric analysis that could be applied clinically, and it marked the end of the era of "model diagnosis."[13]

In the analysis, specific linear and angular measurements are chosen as the basis for specific comparisons between the patient and an ideal profile, skeletal relationship, and occlusion. By plotting a set of values on graph paper, the individual's conformity with the ideal could be seen as a set of "squiggles." The standards developed for the Downs analysis are still useful but have largely been replaced by new standards.[7]

ANB angle

Even before completing his master's requirements at Northwestern University, Richard A. Riedel (1922-1994) (Fig 7) introduced one of the most widely accepted diagnostic cephalometric measurements in use: the ANB angle.

Point A is the deepest cephalometric point in the bony concavity in the midline below the anterior nasal spine, often called the maxillary apical base. Point B is the deepest point in the profile curvature of the mandible, often called the mandibular apical base. Point N (nasion) is the junction of the nasal and frontal bones in the sagittal plane.[14] Thus, angle ANB represents the anteroposterior relationship of the maxilla with the mandible.[15] The analysis growing out of the concept of the ANB angle is considered the second major analysis

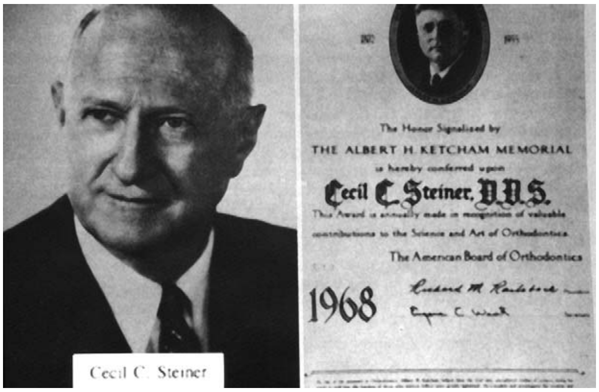

Fig 8. Analysis of Cecil C. Steiner, with its step-by-step approach, was seen as answer to extraction question.

(after Downs's). In addition to his cephalometric research, Riedel's studies at the University of Washington of long-range treatment stability have left us an unsurpassed legacy.[16]

Steiner analysis

Cecil C. Steiner (1896-1989; Angle School, 1921) (Fig 8) was Angle's second student at the Pasadena school but initially was not welcomed with open arms. Angle was looking for dentists who not only "had it in their hands," but who were also widely read. So Steiner was initially rebuffed because he didn't know who Charles Darwin was. But with Mother Angle's encouragement, he not only gained admission but eventually became a household name in orthodontics. He was also the impetus

Fig 9. Viken Sassouni's analysis was based on "sunburst" of rays emanating from central point.

behind construction of the first building dedicated exclusively to the study of orthodontics.

The Steiner analysis, published in 1953, offered specific guides for the use of cephalometric measurements in treatment planning, based on what compromises in incisor positions would be necessary to achieve normal occlusion when the ANB angle was not ideal. It also incorporated arch length and other considerations, such as the profile, enabling even the neophyte orthodontist to determine, for example, if extractions were necessary. Through this step-by-step approach, the Steiner analysis has been instrumental in "popularizing" cephalometrics. At one time, southern California was known cephalometrically as "Steiner Territory."[17]

Tweed triangle

Building on Margolis's research, Tweed determined that, in normal occlusions, the mandibular incisors are upright over basal bone, that is, at approximately a 90° angle to the mandibular plane. From this hypothesis he constructed a triangle (1954) formed by the lower central incisor (LI), mandibular plane (MP), and Frankfort horizontal plane (FH). In the "ideal" Tweed triangle, FH/MP = 25°, LI/MP = 90°, and FH/LI = 65°. By means of this triangle, one can deduce whether or not the case calls for extraction of the 4 first premolars.[18]

Archial analysis

The Sassouni analysis (1955) was the first analysis to stress both vertical and horizontal relationships and the interaction between vertical and horizontal proportions,[7] focusing on the craniofacial structures and how they relate to each other. Viken Sassouni (1922-83) (Fig 9) recognized that there was an interrelationship between the horizontal anatomic planes, the mandibular plane, the occlusal plane, the palatal plane, the Frankfort plane, and the inclination of the anterior cranial base, indicating a vertical propor- tion ality of the face. In a face that is well-proportioned, these planes converge toward a single point (point O).[9] Although no longer widely used, Sassouni's analysis of vertical facial proportions occupies an important niche in today's overall cephalometric appraisal.[7]

Harvold analysis

Egil P. Harvold (1912-1992), a Norwegian, studied medicine and dentistry in Norway and Germany, obtaining his PhD in anatomy at the University of Oslo (1954). His research in the treatment of orofacial clefts and the genetic factors in cranial and facial development spanned 2 continents, and for these Harvold received many honors. He finally settled on the US West Coast with his appointment as professor of orthodontics and director of the Center for Craniofacial Anomalies at Cal. He was also influential in introducing functional appliances into North America.[19]

The Harvold and the Wits (below) analyses are similar in being oriented chiefly to describe the severity or degree of jaw disharmony,[8] but the Harvold concentrates on the magnitude of jaw discrepancies. Harvold calculated an average length of the maxilla and mandible based on the Burlington growth study. In any given patient, the difference between the "unit length" of the maxilla and the unit length of the mandible indicates the discrepancy between the jaws. This does not take into account the vertical distance of the jaws, which if decreased, places the mandible more anteriorly.

McNamara analysis

McNamara's analysis incorporates many of the above analyses, with James A. McNamara's (1943-) own measurements to indicate tooth and jaw positions more specifically, and relates the jaws in an A-P position to the vertical. As with all analyses, McNamara's is not a completely accurate analysis of craniofacial relationships. All parts of the face are interrelated and one may compensate for another. This complicates the process of treatment planning and determining the exact dental and skeletal relationships independently from one another.

However, its two main advantages are that (1) it relates the jaws through a perpendicular from nasion, thus projecting the difference in the A-P position of the jaws to an approximation of true vertical, and (2) the norms are based on the well-defined Bolton sample.

Published in 1983, the McNamara analysis has stood the test of time. It combines elements of previous approaches (Ricketts and Harvold) with original measurements to attempt a more precise definition of jaw and tooth positions.[7]

Wits analysis

The Wits analysis (1967) gets its name from the University of Witwatersrand in South Africa; it was brought Stateside by Alexander Jacobson of the University of Alabama. Rejecting dependence on the ANB angle, Jacobson relates A and B linearly by verticals from the occlusal plane.[20]

Like the Harvold analysis, the Wits analysis concentrates on the skeletal discrepancy between the jaws. It determines the magnitude of the jaw discrepancy by relying on the *linear* difference between points A, B, and the occlusal plane. The Wits takes into account the horizontal and vertical relationship of the jaws, but its weakness is that it is influenced by the dentition and therefore skews the analysis from indicating the true skeletal discrepancies between the jaws.[7]

Ricketts analysis

Similar to the foregoing analyses in that it tries to determine the proper spatial relationship of the jaws for both esthetics and function, the Ricketts analysis (1960) uses measurements compared with idealized norms based on studies of a significant sample size. This analysis was the mainstay of the original computerized cephalometric system, and at one time was highly popular. Its main drawback is that the standard data for many of the measurements are based on nonnspecific samples.[7]

Mesh diagram

Although the Downs analysis was the first to depict the patient's cephalometric pattern in graphic form, it bore no resemblance to the human profile. The template is one means of filling this need. In 1953 Moorrees introduced the mesh-diagram analysis, a graphic means of illustrating cephalometric deviations from the norm. The diagram is based on a coordinate system of squares that distort in proportion to the severity of the malocclusion. Even though the analysis was not widely accepted initially because the normative relationships were not clearly established, it had the advantage of illustrating deviations from the norm in both vertical and sagittal directions simultaneously.[21]

COMMENTARY

Cephalometric radiography allowed orthodontists to serially measure craniofacial growth.[22] From 1930 to 1950, only research institutions and universities had access to cephalometric equipment, but when Margolis introduced his head holder (1950), cephalometrics came down from its ivory tower and went to work as a clinical tool.

In his analysis, Downs reduced the whole skull pattern into the basal skeleton and denture components. He added classification of the facial structure to the previous classifications of Angle. Other analyses, such as that of Steiner, focused mainly on profile relations but included other morphologic features. Björk developed a concept of facial patterns following phylogenetic and craniometric observations, and discussed the implications of growth. Cephalometric researchers, like anthropometrists of old, thought that measurement alone represented scientific endeavor. We now realize that some of these measurements have no real meaning.[22] However, the individual clinician must still be the judge and exercise his or her common sense.[23]

Note: In Chapter 2, the fact that Martin Dewey was 1 of the "Big 4 of Orthodontics" was omitted. We regret the omission.

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