Analysis -- The Interim

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This discussion was formulated in 1968 in commemoration of one of my mentors, Dr. William B. Downs, on the twentieth year after his presentation to the profession of the first, purely so-called cephalometric analysis for the orthodontic clinician. Although others had preceded Downs with certain measurements, it was his work in 1948 that moved cephalometrics out of the research laboratory and, more importantly, it was his ideas which served as the catalyst for developments in the past two decades toward clinical application.

A second reason for this writing is to attempt to clarify some of the misconceptions or confusions regarding clinical cephalometric use as Downs originally intended.

Most clinicians cry for simplicity, yet practically every investigator may select unproven pet points and angles in alarming complication. There is no paucity of new items, many of which often measure the same factor again as measured before in a different manner, and therefore confuse. One good example is the argument about point A.

Downs, seeking a point at the anterior limits of "basal bone" in the upper jaw, selected a point between two maxillary processes—the anterior nasal spine and the alveolar process. This was a working point to represent the location of the maxilla in profile description. Every so often, this factor is brought up and discussed all over again. Some insist on selecting a lateral point to the midline which is on a curved portion of bone and can't be selected with certainty in the bony profile. Others select a point at the apex of the incisor root which is readily modified by moving the root of the tooth and is nothing but alveolar bone. True, the conventional A point is modified with treatment, but so is all of the bone in the maxilla with steady forces of proper intensity. Most clinicians eventually return to Downs' selection as the best solution for maxillary orthopedic registration, despite its problems.

Downs recognized a difference between the bony chin and the alveolus of the lower arch because two anterior points of identification were selected on the mandible. The first was pogonion on the anterior curve of the symphysis to which he related the upper incisor through the use of the APo plane; the other was B point, selected to represent lower denture base. However, point B also changed with tooth movement or eruption, so restrictions came to be built into point B as an index for evaluation of, or reliability for, denture orientation. Ricketts ultimately came to relate the *lower incisor to point A* through the medium of the APo plane. The lower incisor was treated as a reciprocal unit between the *two* bases. In other words, we came to the idea of adjusting the teeth harmoniously between the two bases which meant that the teeth could not be related to only one denture base but to both. The location of the denture varied, as do all physical measurements, and no single position was always recommended.

Downs divided his analysis into the bony structure of the face, with its housing, and some current parameters for denture description. In essence, his goal was to quantitate what previously had been judged by visual impression and subjectivity. Downs loved his stu-

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dents and was deeply concerned with their learning of the factors he thought pertinent to the harmonizing or balancing of the denture to the patients' individual characteristics in the most satisfactory, permanent and esthetic manner.

Downs also gave classification to facial types. The combination of his described chin positions, secondarily related to maxillary locations, yielded a classification of convexity. This added a dimension to orthodontics which had been sought for years through the use of gnathostatic models which became preempted through the tool of cephalometrics.

Downs further observed and described the "swing" of the face during growth and treatment. He consequently was one of the first to give value to a swing (forward or backward development of the chin) as related to anchorage in treatment planning. Although this was approached on a subjective basis, the actual mechanisms were not worked out systematically. He conceived intuitively that which has recently become more objective. He brought consideration to longitudinal factors which he wished to be recognized in posttreatment periods. He explained certain growth factors as a primary cause of relapse.

It is unfortunate that Downs' mission has not been better understood. Ironically, some of those who conceived of this method as a means of case introspection were the champions of extraction in orthodontics at Downs' time. He presented cephalometrics in an era when the support for extraction was at its highest and the deemed limitations of treatment *without* extraction were the greatest. Cephalometrics therefore came under ridicule of those who were the staunch proponents of nonextraction. As an argument against extraction, the *tool* of cephalometrics itself became the target, rather than the interpretation of the method being the objection. Clinicians rejected the headplate x-ray method when the standards disagreed with their ideas, rather than establishing their own standards of objectivity, describing ranges of acceptability or searching for deeper biologic interpretations in support of their beliefs. It was like rejecting plaster casts rather than objecting to the findings therefrom.

Some insisted that cephalometrics was not a tool for treatment planning but only a research method for growth or to tell the clinician where he had been. Some concealed themselves behind the big word "type" without first describing or classifying what was meant by type in the first place.

There is an old parlor game we knew as children called "Pin the Tail on the Donkey." The contestant would be blindfolded and spun around until dizzy and then was directed toward a wall on which a paper donkey was posted. With the tail in hand the player placing it closest to the correct spot on the rear was the winner. Everyone was gleeful at the absurd positions in which the tail might be stuck. So it is with using cephalometrics, only to see where you have been after you have already nominated a conclusive treatment plan. It's like having the blindfold removed to see in what ridiculous spot you placed the tail. It's also a little like building a house with no previous design.

There are controversial problems with analysis in cephalometrics. Its use and its intent are not clear. Cephalometric analysis has been interpreted to be the *end,* which is an error.

Wylie alluded to the method as the numbers racket. Clinicians were trying to establish treatment by adjusting figures alone, on a static basis. Also, by the interpretation of various schemes, distinctly opposite conclusions were reached in the same patient, which were confusing, especially to the beginner. This also led many away from reliance on information that could be derived from the cephalometric procedure.

In spite of its original intent, some latched on to the headplate to help verify previously-conceived recommendations and beliefs. With so many ramifications, a myriad of analyses developed as a confusing and bewildering problem to many. Some analyses came to be limited to the profile alone with no provision for introspection, while others were so complicated as to be unusable for even the advanced clinician. Many were not really analytic because they focused essentially on only one tooth or the mandible alone. Such was the climate.

A clear vision of Downs' perspective is not immediately apparent because the subject of cephalometrics is not one simple aspect. The subject is separated into five categories, at least for teaching purposes. Cephalometrics is not the basis for a cult within the profession, but a truly scientific method if properly employed.

Thus, in the teaching of cephalometrics, the problem of designing and selecting equipment, exposure factors, profile shadowing, positioning patients and processing of film are all considered in the first category—technique.

The *second* problem in the use of cephalometrics is reading the film and making subjective appraisals. Gross form and structure and the gaining of insight into physiologic and biologic phenomena have come to be appreciated much the same as a routine x-ray diagnosis with the intraoral or medical film. Soft tissues of the nasopharynx, tongue and lips are evaluated.

Tracing and the location or identification of points or areas of reference are the *third* category of cephalometric usage. Analysis by the use of combinations of points in relative patterns provides quantitative values to previous qualitative guesses. When loose, unrelated phenomena become subjected to mensuration, scientific theory therefore becomes plausible. Communication is made possible by the cephalometric technique regarding variables and relations not considered in the past. Critical descriptions of relations become evident through the use of systems of measurements. Classifications and breakdown for understanding are appreciated. Means of comparisons make a clinical longitudinal-evaluation sensible at the clinical level.

Steiner has insisted that no responsible clinician fulfills the possibilities he can offer patients without the insight and information gained by cephalometric procedures.

However, the problem of interpretation became the melting pot for arguments. The selection of standards for comparison or objectivity became dogmatic and clouded. Some standards were biased, being selected as averages of samples considered "normal." Others were purely arbitrary on the basis of personal preference of a single patient. The search was on for samples to be employed for objectivity. But in order to prove the selection of values, many other factors were involved, the main one being the original intent of cephalometrics—its use for longitudinal comparisons.

Therefore, the vast need was not only to employ the technique to describe growth changes, but also to identify changes induced by treatment or to monitor results. The separation of growth from treatment became the challenge of the two decades since Downs' inauguration of cephalometrics to clinical practice. This became a *fourth* category of cephalometric application for purposes of teaching, i.e., methods and findings of serial growth and treatment.

Then came the problem of objectives. A true test of any orthodontic standard would not be "normals" but would be successfully-treated patients because patients structurally may never fall into the range of morphology of "normal" samples, either before or after treatment. Morphology varies so extensively that it may be impossible to achieve normal relations with orthodontic treatment. For this reason the normal, or a selected ideal, may be the *guide* but the successfully treated case must be the standard. Therefore, successes and failures on a broad scale needed investigation. In the beginning preliminary treatment studies on inadequate samples had fit so closely the ideas conceived by other longitudinal investigations that broad *assumptions* were unfortunately adopted as irrevocable fact. Controlled scientific studies of adequate samples for changes during treatment were not forthcoming until 1960 and, even then, either were not accepted or were deemed inconclusive by those holding tenaciously to the belief of the possibility of alveolar modification only, by orthodontic treatment.

Downs assumed that any clinician must judge his problem in light of his knowledge of that which can be accomplished. The most useful tool for this determination, as he suggested, has proven to be cephalometrics at the clinical level.

The question arises, what good is information on morphology, growth or induced changes if such knowledge cannot be applied to the patient? What good is research on growth and treatment if it is only academic or for the love of knowledge for the investigator alone? Only when it can be applied to patients routinely at the clinical level does research reach the common good.

The real significance of cephalometrics is to apply the information derived from findings on a clinical basis. This includes the three practical areas: (1) the characteristics of the structural pattern of the cranium, face, malocclusion and musculature, which may be called simply *morphologic descriptions;* (2) *natural growth* impulses and developmental characteristics in the absence of treatment; and (3) *changes* in structure and relationships made possible by mechanical or physiologic therapeutic regimes.

In other words, the above idea shows the use of cephalometrics to be a tool for the application of past findings to the future of a given patient. It is the need for a forecast, design or visualized proposal for treatment. This need became the *fifth* or final category in Downs' teaching. It took on the form of synthesis or the creation of a new objectivized prognosis or cephalometric design. The first predictions were proposed to us by Downs.

Because the selection of treatment is generally critical, a planning procedure must be reasonably accurate for those sophisticated in the selection of a treatment plan. Those orthodontists basing treatment only on expansion, with blind faith in growth or nature to accept the outcome, have little need for treatment planning with more precise methods. Conversely, those basing treatment only on arch length or imbrication or spacing exhibited in the plaster cast have little need for cephalometrics or growth consideration in treatment planning. Cephalometrics only comes into perspective for the clinician, awake to the role that growth and orthopedic or physiologic change can play in the carrying out of his therapy, and to him who is critical of his treatment.

All growth is not alike. All malocclusions are not the same in kind or extent. If growth and developmental changes are to be a part of treatment planning, they must be *built into the plan* in a definite manner, else the clinician must treat the patient solely as a game of chance. If such is not the case, all the research on growth for the last half century is of no practical value.

If growth characteristics can be applied, or if vectors with even small hope and promise can be employed for advantage, the probabilities for success have been improved. If known possibilities of induced changes of skeletal morphology can be made directly available by a technique, the chances of success are increased for each individual. In a negative sense, if known phenomena adversely affect the chances of success or probability of failure, that too should be known. Negative or alarm aspects become equal factors in the selection of the design.

Thus, the original skeletal or morphological description or the so-called cephalometric analysis is not the end. Neither is growth or treatment progress analysis the end. Both are *interim steps* in the complete cephalometric application. The real end is treatment planning by encompassing growth and physiologic change in a direct manner.

The word "prediction" is a semantically loose term. It has a certain finality, prophecy, or divinity which is not intended. More acceptable terms might be estimation, projection, or even a cephalometric design or setup. Maybe the simplest description would be an idealized or objectivized prognosis or a dynamic working plan. Borrowing from business semantics, we now like the word "forecasting." The full understanding of this word makes it the most attractive concept and it is not to be confused with the weather forecaster.

It has been supposed by many that effects could not be induced beyond the alveolar process by orthodontic procedures. Light or mild extraoral forces of intermittent character led to this conclusion. If physical forces could change nothing but alveolar bone, the role of environmental factors on skeletal behavior was largely discounted. The case for genetics or heredity as almost the sole factor of skeletal etiology was prevalent in the thinking of most investigators and scholars during the 1940's and 1950's.

However, events and observations in the past fifteen years have caused many to change their minds to some degree. The basic idea of "pattern" still remains. But, there is certainly an interworking of genetic directives with the total *aggregate* of environmental factors. It becomes a question of the "input" into the system. In our experience, some changes observed in patients having undergone treatment cannot be duplicated in nontreated individuals. We can only conclude that orthodontic treatment, particularly extraoral traction or continued vigorous force, alters skeletal parts not previously thought to be affected.

These cephalometric observations of treated patients revealed possibilities and cast new light on the concept of environment as an etiologic phenomenon.

To reiterate, the cephalometric analysis is not the end but the interim. The original analysis becomes nothing more than a working model for complete treatment planning. It becomes a positive template.

Analysis— Morphologic Description Only

The fundamentals of any adequate clinical cephalometric analysis consist of simple representatives of typal descriptions of the skeletal and denture configurations or patterns. The rudiments are parameters of facial depth, facial height, and the lost third facial dimension, width. Description of the bony profile contour also is employed as a basis for relating tooth positions and denture locations. Frontal cephalometric dimensions must be employed for all width evaluations. Finally, muscular considerations and physiologic mediums are deduced. The question is, what are the most useful cephalometric parameters for these descriptive purposes? In addition, what are the best systems of measurement for growth and treatment changes?

If growth is to be applied as an adjunct to treatment, how can it be *visualized* and given direct value? Is all growth to be given the same value or does physiologic or directional change alter its benefit? A difficulty arises in application because treatment for the patient must be planned in the light of the treatment itself. The plan must be built with induced changes respected. In other words, the forecast is dependent on inputs as well as expected outputs.

In order to visualize the effects of growth and the "swing" of the face or the mandible which I believe Dr. Downs was intuitively describing, the illustrations, Figures 1, 2, and 3 have been employed.

It will be observed that two different situations are represented as extremes by the XY axis angle (Y axis to basion-nasion off 90°) in Figure 1. One, the mandibular prognathic type (deep face), is plus 10 degrees or 100 degrees to basion-nasion. The second is a retrognathic type of minus 10 degrees or 80 degrees (shallow face). Growth in these types (Fig. 2) with no change in pattern reveals different amounts of mesial movement of the lower molar in space. This shows that the continued "growth pattern" is quite significant to treatment consequences.

However, of greater concern, if the Y axis is rotated either by a *change* in growth direction of the condyle or by muscular kinesiological change, the effects of growth at the occlusal level are altered remarkably (Fig. 3). The

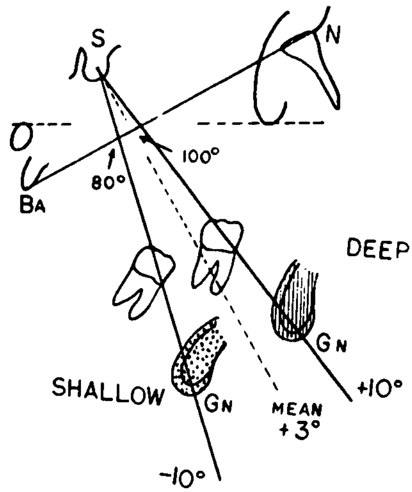

Fig. 1 Variation in chin positions expressed in terms of the Y axis right angle variation from basion-nasion plane. In +10°, the chin (relative to the floor of the brain case) is forward and upward (short, deep face), carrying with it the lower molar. In —10°, the chin is reflected downward in retrognathic type (short or long, shallow face) depending upon length. The population reveals a +3° average with a standard deviation of ±3° (93±3). This use of this angle is excellent for the purpose of typing and for analyses of changes of growth and treatment because the complete base is represented by basion-nasion.

effects of a three-degree rotation of the Y axis are shown. In the retrognathic type, opening three degrees more during the growth change of 2 cm, the molar is seen to move mesially only 2 mm. During the same 2 cm growth, a patient with a beginning plus 10 XY axis and closing three degrees on the Y axis expresses 24 mm in the forward direction. Thus, identical amounts of growth result in twelve times more forward movement of the lower molar in one circumstance compared to the other when the eruptive tendencies are similar.

When it is realized that Y axes have been observed to open six degrees with treatment in three years, and close five degrees without treatment within a period of five years, we realize that

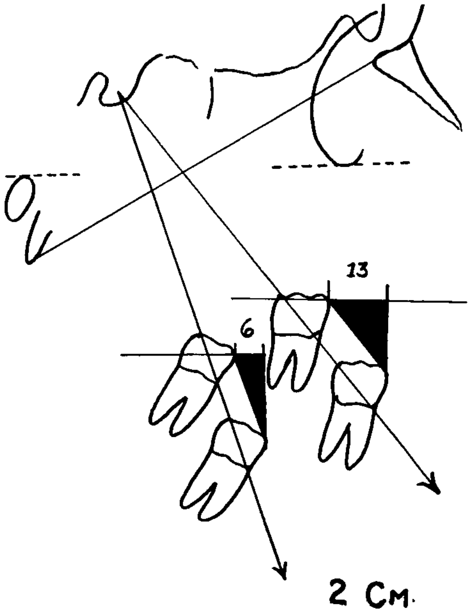

Fig. 2 Effects of growth directions in nonchanging patterns.

During the interval of time of eruption of the lower first molar and the second molar, the mandible will have grown about 2 cm. In nonchanging retrognathic types (—10°, see Figure 1), the downward vector is greater than the forward vector. Two centimeters of growth result in only 6 mm forward movement of the lower molar in horizontal behavior. In the deep face, growing on a nonchanging basis, 2 cm results in a 13 mm forward vector.

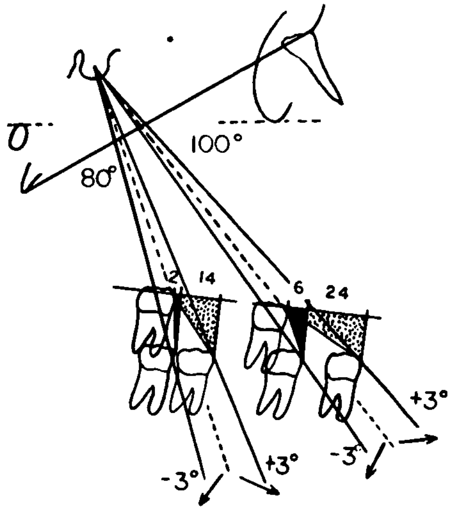

Fig. 3 Difference in the effects of change in direction of the Y axis on the horizontal behavior of the molar in shallow and deep faces. Compare the above with Figure 1 and Figure 2. Retrognathic growth (shallow) type, growing the same, 2 cm, but opening 3° (from —10° to —13°) caused a cancelling out of 4 mm of forward movement (6 mm to 2 mm, respectively). Effects of closing 3° in this shallow type improved forward vector 8 mm (from 6 mm to 14 mm). This shows the dramatic effect of mandibular rotation (opening or closing of the bite) on the horizontal behavior of the molar. Clockwise rotation is observed clinically in certain developing open-bite patients.

In the deep face, normally expressing 13 mm of forward movement with 2 cm growth, a 3° opening cancelled 7 mm of forward movement (13 down to only 6). This behavior is seen in treatment of Class III patients but is unfavorable in Class II correction because the chin becomes relatively retracted due to condyle and mandible rotation in the glenoid fossa. When a deep face closes farther, the forward growth together with rotation makes forward movement of the molar actually greater than the 2 cm of normal growth. It goes to 24 mm and adds about 1 cm to the nonchanging pattern. This is observed in the growth pattern of some cleft palate patients. This behavior can be encouraged in Class II patients treated with proper depression mechanics.

growth *tendencies* are indeed of paramount significance to prognosis.

Too much has been made of so-called cephalometric analysis, but too little attention has been paid to cephalometric application to conceived growth and change in treatment planning. To say it again, cephalometric analysis is not the end in planning, it is the interim. The end must be some logical medium to visualize the benefits or restrictions of growth and change for the individual. This means some sort of projection exercise with new tracings, i.e., a working model with architecturally designed and drafted working plan.

Practical Application

In practice the clinician may give a patient every benefit of the doubt and project growth of the jaws or move teeth under the most hopeful circumstances. Even good growth may not always permit esthetic and functional equilibrium under pleasing or acceptable standards, meanwhile maintaining all the teeth. When this results, the orthodontist either extracts teeth as an aid or may turn to orthopedic or surgical help as another aid to dental and skeletal balance, stability and health.

When this thesis is accepted, the visualization by a cephalometric setup or some estimation exercise is not an impractical pipe dream. It is a product of reality and I am sure was in the mind of Downs without material manifestation.

Oddly enough, the arguments against cephalometric synthesis do not center on the philosophy of the idea of growth but on the *projected objectives* of jaw and tooth relation. We have pressed forward for the use of the APo plane as a useful reference line for tooth relation in the cephalometric setup. Point A is changeable by orthodontic treatment and pogonion or the chin is influenced by growth and mandibular rotation. Thus, probably the biggest controversy today is the need of correction of facial convexity. Does the orthodontist treat the denture to the skeletal convexity, or should an improvement of the structural profile be a paramount objective? If the latter prevails, exactly how much correction will occur naturally with maturation?

The essential in employing a dynamic setup is to first locate the chin in space, by using basal-cranial references; second, orient the maxilla or point A in the profile in the most sensible and desirable or practical skeletal harmony for the individual; and third, erect a new A-pogonion plane which serves as a medium with which to locate the denture. As a working hypothesis, based on accumulated studies, the mean convexity at age nine for both sexes is +2.0±3.0 mm. In extreme convexity, the best that may be hoped for may still be moderately convex. Theoretically, the more A point is reduced, the farther lingually the lower incisor must be related in order to maintain the same relation to the APo plane unless the denture is "rabbited." The relationship of the occlusal plane is maintained proportionally to the upper and lower jaws.

Where should the denture be oriented to the APo plane and occlusal plane?

Our one thousand orthodontic cases suggested a working hypothesis of +0.5 ±2.5 mm, which was almost identical to Downs' findings. However, our cross section of one hundred nonorthodontic adults, age 55, revealed +1.5±3.5 mm as a yardstick for the lower incisor to APo. Another nontreated sample, using twenty girls and twenty boys, showed the lower incisors to be +1.0 mm ±1.5 mm. "Smile of the Year" contest winners show dentures to be slightly more protrusive than Downs' normals and more in harmony with other cross-sectional standards, i.e., +1.5±3.0 mm.

The normals frequently employed for standards represent patients with big, loose, flaccid lips with wide mouths. Should these normals be the ideal of objectivity in the orthodontic population with already restricted arches and severe imbrication, and possibly tighter lip musculature? Are the parameters of lower incisors wide enough to be practical for current orthodontic practice?

It has been emphasized, and so did Downs insist, as well as all orthodontists who think biologically, that ranges of variation be recognized. Dentures are not stereotyped in planning nor could ideals always be gained even if planned. We usually work toward an appreciated standard or ideal as the goal, the same as Angle idealized "Old Glory." If the orthodontist accepts the optimal range in position of the lower incisor to be 0.5 to 1.5 mm anterior to the APo plane with one standard deviation of about 2.5 to 3.0 mm, this leaves ample total range for location of the denture as "keyed" from the lower incisor, i.e., up to 5 mm protrusion of the lower incisor as within a clinical norm.

The idea is to be able, with conceived growth and change, to move the teeth forward of the APo plane as far as possible without producing pursing and lip strain, ugliness, and ultimate imbalance and instability. Thus, the consideration of musculature directly enters into treatment planning, as well as longer-range, longitudinal growth phenomena.

However, it has been observed that, in most malocclusions, facial lengthening and denture protrusion both contribute to lip strain and mentalis elevation of the soft tissue chin. It is our experience that many patients are not willing to accept the mouth strained and the smile excessively "toothy." Therefore, the closer we attain ideal denture and skeletal standards, the better our efforts seem to be accepted by the public. For some patients this may mean waiting for posttreatment adjustments with long periods of treatment and retention, but these should be planned and explained if they are best for over-all objectives.

Summary

To attempt to explain Downs' total concept, the orthodontist must not confuse static description or analysis with the dynamics of growth, developmental change and treatment effects. Analysis is an interim step. It forms the framework or a working model on which to estimate natural and desired changes and the basis on which to build a plan. Synthesis or forecasting is the end product of treatment planning and was originated by Downs. Serial observation during treatment is the feedback. When the clinician thinks far enough, this idea of synthesis is the logical conclusion and is basic to the selection of an appliance. The working plan or cephalometric setup is a progressive step in cephalometrics for the orthodontist. The end is execution of the total design in harmony with ultimate balance and longevity.

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