Differential diagnostic analysis system

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This article links clinical research to fundamental orthodontic concepts to give the clinician a workable differential diagnosis system. The clinical research, conducted by the Charles Tweed Foundation, attempted to establish a "profile" for the Class II malocclusion correction, which, because of certain characteristics, was destined to failure. The Cranial Facial Dental Analysis integrates this clinical research with the total space analysis to give the clinical orthodontist a useful tool for differential diagnosis. (AM J ORTHOD DENTOFAC ORTHOP 1994;106:641-8.)

Success in any endeavor depends on strategy, discipline, and work. Strategy depends on the intelligent use of information; thus information technology is the key to each orthodontist's diagnostic and clinical analysis.

Diagnosis, treatment planning, treatment timing, and treatment management are closely related parts of an orthodontist's concern for the patient, and each plays a major role in the service rendered. These interrelated criteria must reflect the fundamental knowledge, skill, and philosophy of the orthodontist.

Our objective in preparing this differential diagnosis and clinical analysis article is to incorporate the results of clinical research conducted by the Charles H. Tweed International Foundation for Orthodontic Research with time-tested concepts and values that significantly influence orthodontic diagnosis and the subsequent delivery of a quality orthodontic service to the public.

For a period of approximately 15 years, until his untimely death in 1993, Jim Gramling, Jonesboro, Ark., was the Research Director for the Foundation. During the years he was the Research Director, Dr. Gramling compiled a rather large sample of successfully and unsuccessfully treated Class II malocclusions,[1,2] all of which were treated by members of the Charles H. Tweed Foundation.

Dr. Gramling began collecting the sample in the early 1980s. The stipulation was that the patients had to have been started in active treatment during 1979 or during the 1980s. The reason for the time stipulation was to insure that the clinical material used reflected treatment with the Sequential Directional Force technology that was introduced in 1978. All the data therefore represented similar technology and treatment strategy.

Each member who participated in Dr. Gramling's studies furnished pretreatment and posttreatment cephalometric x-ray films with tracings of specified cephalometric landmarks. The points were then checked by Dr. Gramling for consistency of technique. The pretreatment and posttreatment Frankfort horizontal planes were standardized by means of superimposition on the sella nasion plane. Contributors were not handpicked; anyone who used the Sequential Directional Force technology was encouraged to participate.

At the time he collected the "successful" sample, Dr. Gramling also collected a sample of 55 patients whose Class II malocclusions were deemed unsuccessfully corrected by the contributors. The determination of an unsuccessful treatment result was left entirely to the contributor, although some general guidelines were given to standardize the sample. Each contributor sent a pretreatment and a posttreatment cephalogram of the unsuccessfully treated patient. Frankfort horizontal plane of the pretreatment and posttreatment tracings was standardized by repeating the original porion position with superimposition on the sella nasion plane. The same statistical analyses were performed on the successful and unsuccessful samples. Many values were considered, but the values scrutinized most closely are illustrated in Fig. 1.

The results of the studies of unsuccessful and successful treatment were compared and can be seen in Table I. Note that in the successful sample, the Frankfort mandibular plane angle (FMA) was reduced, the Frankfort mandibular incisor angle (FMIA) was increased, and the incisor mandibular plane angle (IMPA) was reduced. In the unsuccessful sample, FMA increased, FMIA increased but not as much as it did in the successful sample, and IMPA remained the same. There was not as much

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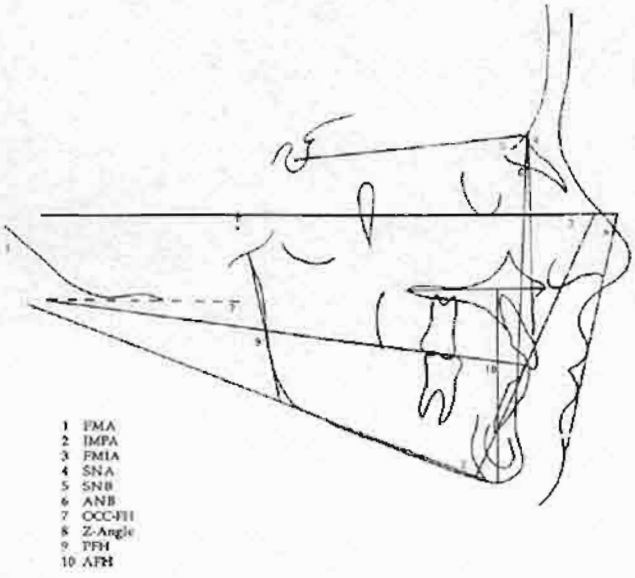

Fig. 1. Cephalometric values used in study of successful and unsuccessful malocclusion correction.

Table I. Comparison of successful and unsuccessful samples

	Successful		*Unsuccessful*	
	Pretreatment	*Posttreatment*	*Pretreatment*	*Posttreatment*
FMA	28	27	29	30
FMIA	58	63	56	61
IMPA	95	90	95	95
Z-angle	66	75	62	69
Y-Axis	62	62	65	65
SNA	82	79	82	79
SNB	76	76	75	75
ANB	6	3	6	4
AOBO	4	−1	7	5

Z-angle increase in the unsuccessful sample as there was in the successful sample. The SNA angle reduction was similar, but AOBO reduction for the unsuccessful sample was not as good as for the successful sample. The Y-axis values and the SNB angle values remained the same for both samples. By studying the collected data from these two samples, it can be concluded that in unsuccessful Class II treatment, the mandibular incisor position is not corrected, or if it is corrected, the correction is subsequently compromised by excessive, unreciprocated use of Class II elastics in an attempt to establish the proper anterior-posterior maxillomandibular relationships.

Table II. Comparison of successful and unsuccessful samples by dividing the samples according to FMA

	Comparisons	
	Successful	*Unsuccessful*
Low Frankfort mandibular plane angle		
FMA	+1	+1
FMIA	+7	−1
IMPA	−6	0
ANB	−3	−2
Z-angle	+10	+8
Medium Frankfort mandibular plane angle		
FMA	+1	0
FMIA	+6	0
IMPA	−6	0
ANB	−3	−3
Z-angle	+10	+11
High Frankfort mandibular plane angle		
FMA	+1	0
FMIA	+4	−1
IMPA	−3	−1
ANB	−2	−1
Z-angle	+8	+6

In the next comparison, the successful and unsuccessful treatment results were divided into high, medium, and low Frankfort mandibular plane angle categories (Table II). According to the data from the low FMA category, the ANB angle changes were not much different between the groups. The big difference was in mandibular incisor position. In the successful orthodontic treatment sample, the mandibular incisors were uprighted more than in the unsuccessful sample. The FMIA was increased 8° more in the successful sample than in the unsuccessful sample. Thus, facial change was more positive in the successful sample. In the medium Frankfort mandibular plane angle category, unsuccessful treatment was about equal to successful treatment, except the mandibular incisors were uprighted more in the successful sample of patients. An analysis of the high angle category showed similar results.

The Class II malocclusion was successfully corrected when the FMA was maintained, the FMIA increased, the IMPA decreased, and the ANB angle reduced. The question, "What is the 'profile' of a patient with a Class II malocclusion whose treatment is destined to failure?" was asked. The general answers became (1) a very high or very low FMA, (2) a high ANB angle, (3) a high AO/BO, (4) a low FMIA or a high IMPA, (5) a steep occlusal plane angle, and/or (6) a very low SNB angle.

Table IIIA. Difficulty factors—weighted variables of the probability index

Probability index variables	
FMA:	Variation - 5 points
ANB:	Variation - 15 points
FMIA:	Variation - 2 points
OcPl:	Variation - 3 points
SNB:	Variation - 5 points

Table IIIB. The probability index

	Point value	*Cephalometric value*	*Probability index*
FMA 22°-28°	5		
ANB 6 or less	15		
FMIA 60 or more	2		
OCC PL 7 or less	3		
SNB 80 or more	5		
		Total	

PROBABILITY INDEX

From the background of evidence established by these studies, Gramling formulated a "Probability Index"[3] for three specific purposes (1) to augment diagnostic procedures, (2) to guide treatment procedures, and (3) to predict possible treatment success or failure.

The purpose of the index was to be of value in isolating those Class II malocclusions that might need alternate treatment procedures or those that might require surgical procedures to affect a complete correction. Gramling's probability index was based on the premise that control of the FMA, the ANB angle, the FMIA, the occlusal plane, and the SNB angle were keys to the success or failure of the orthodontic treatment of a Class II malocclusion. The Probability Index suggested that the following conditions might be necessary for treatment success of a Class II malocclusion.

1. The FMA should be 18° to 35°.
2. The ANB angle should be 6° or less.
3. The FMIA should be greater than 60°.
4. The occlusal plane should be 7° or less.
5. The SNB angle should be 80° or more.

Gramling established a difficulty factor and assigned a specific number of points to each variable (Table IIIA).

In 1989 Gramling studied 40 successful and 40 unsuccessful Class II malocclusion corrections. After studying these 80 patient records, he revised only one of the five premises of the Probability Index. He changed the successful the FMA range from 18°-35° to 22°-28° (Table IIIB).

In a later study of successful and unsuccessful Class II treatment, Merrifield and Gebeck[4,5] studied a successfully treated Class II sample, an unsuccessfully treated Class II sample, and a control Class II sample. As a result of their studies, Merrifield and Gebeck concluded that equally important to successful Class II correction was control of anterior facial height and posterior facial height, or as Gramling concluded by using FMA and occlusal plane, control of the vertical dimension. Posterior facial height (Fig. 1) is a millimetric measurement of ramus height from articulare to the mandibular plane which is measured tangent to the posterior border of the ramus. Anterior facial height (Fig. 1) used by Merrifield and Gebeck is a perpendicular millimetric measurement from palatal plane to menton.

The relationship of posterior facial height to anterior facial height determines both the FMA and the lower face proportion. In the growing child with a Class II malocclusion, ramal growth change and its relationship to anterior facial height in both proportion and in volume is critical. In Class II treatment, it is essential to limit the increase in anterior facial height by controlling maxillary and mandibular molar extrusion and by using an anterior high-pull force on the maxilla.

Merrifield and Gebeck[4,5] stated that ramal height increase was found to be essential to a favorable mandibular response during treatment. *Mandibular response* (Fig. 2) is the term that describes the relative change in the spatial relationship of the maxilla to the mandible. It encompasses growth, development, and treatment change in the horizontal and vertical dimension. Merrifield and Gebeck[4,5] stated that the ratio of change of posterior facial height to anterior facial height was a very valuable evaluation tool both during and after orthodontic treatment. They found that a ratio of two times as much posterior facial height increase as anterior facial height increase was ideal for Class II, Division 1 malocclusion correction and for dentoalveolar protrusion reduction. However, even more important than the ratio was the volume of change. For example, a 10-mm posterior facial height increase with a 5-mm anterior facial height increase was found to be more beneficial to the correction than a 4-mm posterior facial height increase and a 2-mm anterior facial height increase.

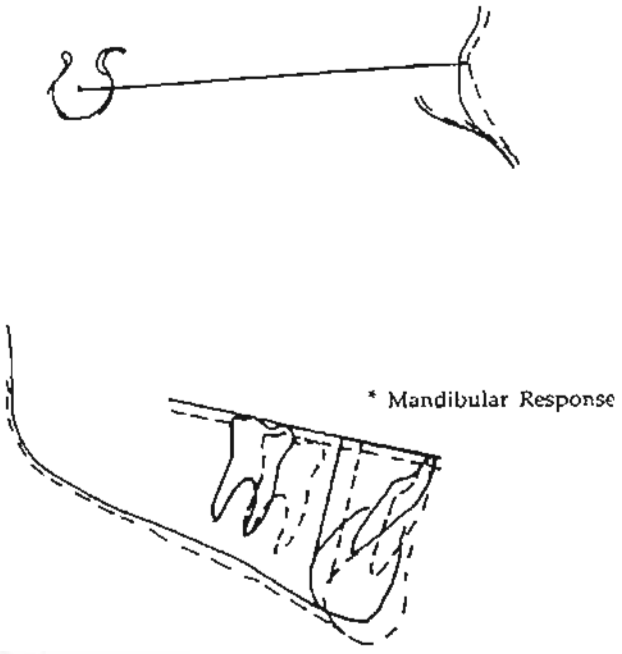

Fig. 2. Mandibular response measured along the original occlusal plane.

In 1989, Andre Horn studied and researched the relationship of anterior and posterior facial height. Horn suggested a Facial Height Index or FHI.[6] The normal posterior facial height to anterior facial height ratio was found by Horn to be 0.65 to 0.75. If the FHI value was below or above this range, the malocclusion was a great deal more complex and the difficulty encountered in correction was increased. For example, an index of 0.80 was severe and indicated a patient with a low FMA with either too much ramal growth or too little vertical anterior face height. As the index approached 0.60, the cranial facial pattern was one of a severe vertical discrepancy that demonstrated too little ramal height or too much anterior facial height.

CRANIAL FACIAL ANALYSIS (TABLE IV)

The Cranial Facial Analysis has been developed from Gramling's work, from Merrifield and Gebeck's work, and from Andre Horn's ratio studies. The Z angle has been substituted for the FMIA because it is a better indicator of facial form. Horn's Facial Height Index was added to further define horizontal and vertical relationships of the craniofacial complex.

Each cephalometric value used has been determined to have significant merit. The interrelationship of these key values has been weighted in relationship to their significance and mathematical value. In determining the difficulty of correction, the areas were weighted taking into consideration the necessary diagnostic decisions and the complexity and importance of treatment management.

When the cranial facial analysis is used in conjunction with the total dentition space analysis, (Table V) the clinician can determine the complexity of the major clinical aspects of a malocclusion. Use of both analyses will significantly improve the clinician's ability to diagnose, plan, and execute treatment. The sum of the cranial facial difficulty and the total dentition space analysis difficulty is the cranial facial dental total difficulty. This figure gives the clinician a quantitative method of evaluating the difficulty of correction of each malocclusion. The analysis (Table VI) identifies the specific areas of major disharmony—cranial, facial, or dental, and gives guidance for treatment strategy. Other clinical relationships and values, such as habit evaluation, joint health, muscle balance, dental malrelationships, and the other cephalometric values, must be duly noted and evaluated by the orthodontist. The orthodontist must also evaluate the patient's motivation and desire for orthodontic correction. The range of values for the total difficulty index that have been found to be most appropriate are as follows:

1. Mild—0 to 60.
2. Moderate—60 to 120.
3. Severe—120 plus.

The cranial facial dental total difficulty index can be a very valuable tool in patient and parent consultation because it will help the clinician explain diagnosis, treatment, treatment timing, and treatment management. The use of the cranial facial analysis, the dentition space analysis, and ultimately, the cranial facial dental difficulty index will be illustrated with the analysis of pretreatment records of a Class II, Division 1 malocclusion.

The pretreatment facial photographs (Fig. 3) exhibit a very convex facial profile with maxillary protrusion, mandibular retrusion, lip eversion, and strain of the mentalis musculature. The pretreatment casts (Fig. 4) illustrate the Class II dental occlusion, the deep overbite, crowding, and excessive curve of Spee. The pretreatment panoramic x-ray film (Fig. 5) exhibits a blocked out mandibular right second premolar, a retained maxillary left second deciduous molar, and unerupted maxillary and mandibular second molars. The third molar buds are present. The pretreatment cephalometric tracing (Fig. 6) confirms a skeletal imbalance with flaring of the mandibular incisors, and a relatively steep occlusal plane angle of 13°.

Table IV. Cephalometric values and cranial facial analysis

	Normal	Pre Rx	Progress	Progress	Final
FMIA	67°				
FMA	25°				
IMPA	88°				
SNA	82°				
SNB	80°				
ANB	2°				
AO-BO	2 mm				
Occ Plane	10°				
Z Angle	75°				
Upper Lip	=				
Total Chin	=				
Post Face Ht	45mm				
Ant Face Ht	65mm				
Index Post/Ant	.70				

CRANIAL FACIAL ANALYSIS Normal Range	Ceph Value	Difficulty Factor	Difficulty
FMA 22° - 28°		5	
ANB 1° - 5°		15	
Z Angle 70° - 80°		2	
Occ Plane 8° - 12°		3	
SNB 78° - 82°		5	
FHI (PFH-AFH) .65 - .75		3	
C.F. Difficulty Total			

Table V. Total space analysis

TOTAL SPACE ANALYSIS	Value	Difficulty Factor	Difficulty
Anterior			
Tooth Arch Disc.		1.5	
Headfilm Disc.		1	
Soft Tissue Mod.		5	
TOTAL			
Midarch			
Tooth Arch Disc.			
Curve of Spee			
TOTAL		1	
Occlusal Disharmony (Class II or Class III)		2	
Posterior			
Tooth Arch Disc.			
Expected Increase (-)			
TOTAL		5	
		Space Analysis Difficulty Total	
Space Analysis Total			

Fig. 3. Pretreatment facial photographs.

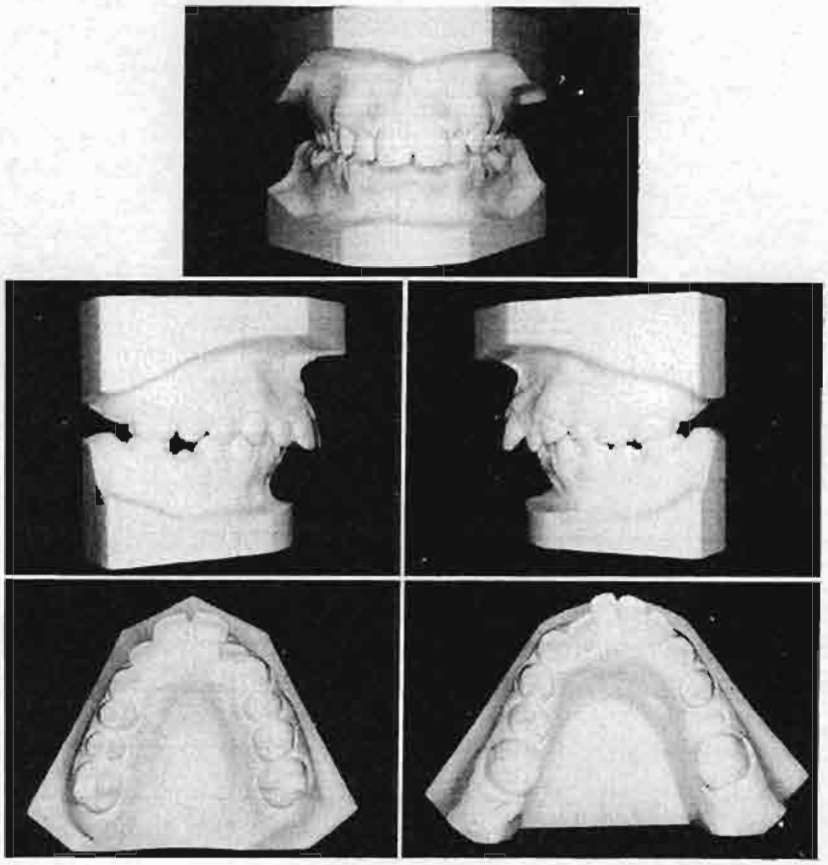

Fig. 4. Pretreatment casts.

Table VI. Cranial facial dental analysis

CRANIAL FACIAL ANALYSIS	Ceph Value	Difficulty Factor	Difficulty
Normal Range			
FMA 22° - 28°		5	
ANB 1° - 5°		1.5	
Z Angle 70° - 80°		2	
Occ Plane 8° - 12°		3	
SNB 78° - 82°		5	
FH/mandib .85 - .75		3	
C.F. Difficulty Total			

TOTAL SPACE ANALYSIS			
Anterior	Value	Difficulty Factor	Difficulty
Tooth Arch Disc.		1.5	
Headfilm Disc.		1	
Soft Tissue Mod.		5	
TOTAL			
Midarch			
Tooth Arch Disc.			
Curve of Spee			
TOTAL		1	
Occlusal Disharmony			
(Class II or Class III)		2	
Posterior			
Tooth Arch Disc			
Expected Increase (-)			
TOTAL		.5	
		Space Analysis	
Space Analysis Total		Difficulty Total	

C.F. Difficulty Total	
S.A. Difficulty Total	
Total Difficulty	

Index Difficulty: Mild 0 - 60 Moderate 60 -120 Severe 120+

The cranial facial analysis (Fig. 7)

Each cephalometric value that is used in the cranial facial analysis is placed in the "ceph value" column. The difficulty factor is calculated for each cephalometric measurement that is outside the normal range. The total cranial facial difficulty for this patient was 82.

Total dentition space analysis (Fig. 7)

The total space analysis and space analysis difficulty are calculated. The total space analysis is divided into anterior, midarch, and posterior. The anterior tooth arch discrepancy for the six mandibular anterior teeth was 4 mm. This figure becomes 6.0 mm in the difficulty column since anterior crowding, because it is overriding, has been given a difficulty factor of 1.5. The head film discrepancy was 14.4 mm (0.8 × 18). There was no soft tissue modification because total chin thickness equaled upper lip thickness. The total anterior space analysis difficulty was 20.4 mm.

The tooth arch discrepancy for the midarch was 4 mm. The curve of Spee required 3 mm of space for leveling. The difficulty factor for the midarch is 1, therefore the total space requirement for correc-

Fig. 5. Pretreatment panoramic x-ray film.

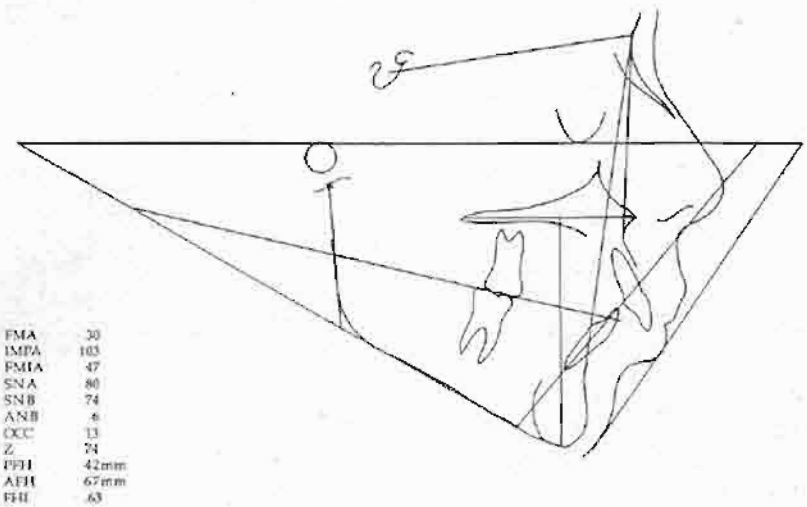

Fig. 6. Pretreatment cephalometric tracing.

tion of crowding and the leveling of the curve of Spee was 7.0 mm (4 + 3 × 1). The patient had a full step Class II occlusion on both right and left sides. The 5 mm of space per side was necessary for correction. Because occlusal disharmony has a difficulty factor of 2, the total difficulty for Class II correction was 20 mm (5 + 5 × 2). The total midarch difficulty was therefore 27.5 mm.

The tooth arch discrepancy in the posterior part of the arch, measured from the distal of the first molar to the ascending border of the ramus, was 16 mm. Because the patient was 12, she could expect an increase in posterior space of 6 mm.[7-9] Therefore the space deficit was 10 mm. Because the difficulty factor is 0.5 for the posterior area, the total space analysis difficulty for the posterior denture area was 5 mm. The difficulty factor is lower in the posterior part of the mouth because posterior space requirements can be resolved simply with extraction of third molars.

The actual space required to correct crowding for the dentition was 35.8 mm. However, when the total space analysis difficulty was calculated, the total difficulty was 52.4 mm. This figure included the space requirement for the occlusal disharmony correction, as well as space requirements for the

CRANIAL FACIAL ANALYSIS Normal Range	Ceph Value	Difficulty Factor	Difficulty
FMA 22° - 28°	30	5	10
ANB 1° - 5°	6	15	16
Z Angle 70° - 80°	56	2	28
Occ Plane 8° - 12°	13	3	3
SNB 78° - 82°	74	5	20
FHI (PFH/AFH) .65 - .75	.63	3	6
C.F. Difficulty Total			82

TOTAL SPACE ANALYSIS	Value	Difficulty Factor	Difficulty
Anterior			
Tooth Arch Disc.	4.0	1.5	6.0
Headfilm Disc.	14.4	1	14.4
Soft Tissue Mod.	0.0	.5	0.0
TOTAL	18.8		20.4
Midarch			
Tooth Arch Disc.	4.0		
Curve of Spee	3.0		
TOTAL	7.0	1	7.0
Occlusal Disharmony (Class II or Class III) 10		2	20.0
Posterior			
Tooth Arch Disc.	16.0		
Expected Increase (-)	6.0		
TOTAL	10.0	.5	5.0
Space Analysis Total	35.8	Space Analysis Difficulty Total	52.4

C.F. Difficulty Total	82.0
S.A. Difficulty Total	52.4
Total Difficulty	134.4

Index Difficulty: Mild 0 - 60   Moderate 60 -120   Severe 120+

Fig. 7. Cranial facial dental analysis with total difficulty for patient whose records were illustrated.

correction of crowding and uprighting of the mandibular incisors.

The cranial facial difficulty is combined with the space analysis difficulty to yield the cranial facial dental total difficulty (Fig. 7). Total difficulty was 134.4. By using the criteria already established for difficulty of malocclusion correction, this patient's problem fit into the "severe" category.

The information derived from the cranial facial dental analysis can be invaluable to the clinician during the diagnosis process. It is a tool, but a tool that has clinical importance. It gives the orthodontic specialist information that is useful and can lead to proper diagnostic decisions that will most advantageously facilitate correction of the malocclusion.

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