The Probability Index

James F. Gramling†
Jonesboro, Ark.

The clinical study of the treatment of a sample of Class II malocclusions was made. This information from both successful and unsuccessful Class II malocclusion correction was recorded. The objective of the study was to determine whether there are predictive characteristics of Class II cases that could give, with reasonable accuracy, an indication of those Class II malocclusions that would more readily respond to treatment and those that would have less chance of conventional treatment being successful. This information could give the orthodontist differential diagnostic guidance before starting treatment to determine whether alternative treatment strategy should be considered. The study used five very important cranial and dental cephalometric measurements that individually had significance, but no predictive value. However, these measurements, when combined, and given a weighted value that reflected a relative importance of each criteria, were found to collectively give a predictive capability in determining whether the case was favorable for Class II correction. The five angles selected were (1) the Frankfort mandibular plane angle (FMA); (2) the point A nasion point B, (ANB) angle; (3) the occlusal plane, Frankfort plane angle; (4) the Frankfort-mandibular incisor (FMIA) angle; (5) the sella-nasion-point B, (SNB) angle. The Probability Index is the sum of the weighted values of the five cranial, and dental angles and seems to have significant predictive value in the differential diagnosis and treatment planning of the Class II malocclusion. (AM J ORTHOD DENTOFAC ORTHOP 1995;107:165-71.)

Jim Gramling passed away in June, 1993, after suffering a cerebral hemorrhage. He was 58. At the time of his death he was practicing in Jonesboro, Ark. He was also serving orthodontic education and research as a professor of orthodontics at the University of Tennessee, Memphis, Tenn., and as Director of Research of the Charles H. Tweed International Foundation.

This article was being prepared for submission to the AJO/DO at the time of Jim's death. The final editing for its submission was accomplished by Levern Merrifield, Ponca City, Okla., and James L. Vaden, Cookeville, Tenn. The words and thoughts belong to Jim Gramling.

The research program of the Charles H. Tweed International Foundation began in the 1970s. In those early years, progress was slow; indeed we were groping for a direction. Finally, after a great deal of thought and after many insights gained from observation of consistent failures during the orthodontic treatment of Class II malocclusions, Levern Merrifield, the Chairman of the Board of the Charles H. Tweed International Foundation, suggested a study of Class II orthodontic treatment. It is important to make the distinction that this research was clinical research. Therefore the study that was embarked on was not a study of Class II malocclusions. Instead, it was a study of Class II orthodontic treatment, a big difference.

PAST RESEARCH

A necessary prelude to the presentation of the Tweed Foundation research is a brief summary of the past research projects of the Tweed Foundation. The first of three previous research projects was a study of Charles Tweed's Class II treatment.[1] A random sample of 54 Class II malocclusions were selected from the Tweed library for a statistical investigation. The results of this study were presented to the Charles H. Tweed International Foundation at its thirteenth biennial meeting in 1980. This study showed that Dr. Tweed corrected Class II malocclusions 40 years ago[2,3] about as effectively as they are corrected today. Some Class II malocclusions Tweed corrected quite well; others, not so well. Even Charles Tweed experienced varying degrees of success. His success rate was infinitely greater than other orthodontists of his time; in part because he was a master technician, but largely because he pursued excellence with an incomparable zeal and enthusiasm. The pursuit of that quest for excellence in orthodontic treatment remains open this day to all orthodontists.

The second research project followed closely and was a study of 150 difficult Class II malocclu-

†Deceased.

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sions that had been treated successfully by member orthodontists of the Charles H. Tweed International Foundation.[4] The paper resulting from this study was presented to the Foundation at its fifteenth biennial meeting in 1984. The sample was composed of data from successfully corrected difficult Class II malocclusions. It is important to underscore that this study was not treatment of just *any* Class II malocclusion; it was a study of the orthodontic treatment of *difficult* Class II malocclusions, all of which had been successfully corrected. The study revealed essentially the same findings as the study of Tweed's orthodontic treatment. That is, a wide variety of Class II malocclusions were corrected, some better than others. The question naturally arose as to which Class II malocclusions can be successfully corrected and which cannot; and whether there are distinctive features of a Class II malocclusion that might provide a clue to this very important question. To seek a clue, a third study was instituted.

The third study was another investigation of the orthodontic treatment of difficult Class II malocclusions, *but* this study included only *unsuccessfully* corrected Class II malocclusions.[5] The results were presented to the Charles H. Tweed International Foundation at its sixteenth biennial meeting in 1986. Statistical analysis of the results of these unsuccessful Class II treatments began to show trends. Parallels were evident in the failures that were not seen in the successful Class II corrections. It appeared that there were some cephalometric keys for prognosis. These emerging keys were not cephalometric angles being arbitrarily chosen, they were the angles that statistical analysis was showing to be more reliable in predicting the success or failure of any Class II correction.

Prompted by the reality that there are certain Class II malocclusions that can successfully be corrected, and that there are certain Class II malocclusions that cannot be successfully corrected, a fourth research project was designed; the subject of this article. It is an effort to discover predictive elements of success or failure in Class II orthodontic treatment by statistically analyzing pretreatment and posttreatment cephalometric data.

Any prediction is extremely difficult and no prediction can be perfectly accurate. However, a predictive capability in Class II orthodontic treatment would be of sufficient value to the clinical orthodontist to make this a worthy research project. Indeed a reliable method of predicting the success or failure in Class II orthodontic correction would be of enormous value.

THE PROBABILITY INDEX

This investigation defined the Probability Index. Forty successfully corrected difficult Class II malocclusions and a like number of unsuccessfully corrected difficult Class II malocclusions were compared. The purpose was to search for a means of predicting the relative success or failure in Class II malocclusion treatment. As the data is presented and the evidence revealed, a judgment of the efficacy of the Probability Index can be made.

The elements of the Probability Index are five key cephalometric angles. When properly integrated, they *appear* to be reliable in predicting the prognosis of a given orthodontic treatment.

The first key is the very familiar Frankfort mandibular plane angle,[6] long recognized as one of the most important of cephalometric criteria in diagnosis, treatment planning, and prognosis. This angle, more than any other, delineates the directional quality of facial growth and the interrelation of the vertical and the horizontal dimensions of the face.

The second key is the ANB angle,[7] again a criteria familiar to every orthodontist. This is the angle that specifically *classifies* a malocclusion. There are other angles similar to this angle, but none quite so direct in the expression of the interrelation of the maxilla to the mandible.

The occlusal plane measured to Frankfort horizontal[8] has long been considered as the most direct determinant of the quality of orthodontic forces, and is the third key. It is equally important as a determinant of the difficulty of an orthodontic correction because the malocclusion is corrected along the occlusal plane. In the second study of 150 successfully treated difficult Class II malocclusions, it was the Class II malocclusions with high occlusal plane angles that proved to be the most difficult to correct in many perspectives.

The fourth key is the Frankfort mandibular incisor angle,[9] the third angle of the Tweed triangle. It is the most meaningful of the angles depicting the relative protrusion of the mandibular incisor. The FMIA not only relates the protrusion of the mandibular incisor relative to the mandible, but also it relates the protrusion of the mandibular incisor relative to the face.

The fifth angle used in the Probability Index is the SNB angle.[10] It most clearly and most precisely represents the spatial relationship of the mandible to the cranium. From earlier studies of more than 400 cases, the SNB angle did not change from before to after treatment in virtually all cases.

Please note that the predictive capability of

Table I. Comparison of the FMA of successfully and unsuccessfully corrected Class II malocclusions

	Successful	*Unsuccessful*
Below 20	5	5
20-30	29	15
Above 30	6	20

Table II. Comparison of the ANB of successfully and unsuccessfully corrected Class II malocclusions

	Successful	*Unsuccessful*
6 and below	25	21
7 and above	15	19

these angles is not valid when each is considered separately. The predictive nature only seems to materialize when these angles are considered collectively. The following is an explanation and discussion in support of this hypothesis.

Table I shows data of the sample grouped only by the Frankfort mandibular plane angle. There was a moderate trend; there were more cases that had medium and high Frankfort mandibular plane angles in the unsuccessful sample, but the trend was not clearly decisive. A conclusive judgment of the prognosis of a Class II malocclusion on the basis of the FMA alone could not be made.

Table II shows the sample when divided by the ANB angle and separated into high and low ANB angle groups. This data shows very little difference in the successfully treated and the unsuccessfully treated Class II samples. Again, the size of the ANB angle alone was not a reliable predictor of the success or failure of Class II correction.

Table III shows the sample divided into high and low occlusal plane angle cases. This data revealed even less difference between the successfully treated and the unsuccessfully treated sample. Again, on the basis of the value of the occlusal plane angle alone, no valid prediction could be made concerning the correctability of a given Class II malocclusion.

Table IV shows the data when the sample was divided by the FMIA and separated into high and low FMIA. These samples were virtually identical. The size of the FMIA alone did not provide any prognosis of the correctability of a given Class II malocclusion. Class II malocclusions with low Frankfort mandibular incisor angles corrected al-

Table III. Comparison of the occlusal plane of successfully and unsuccessfully corrected Class II malocclusions

	Successful	*Unsuccessful*
7 and below	8	6
8 and above	32	34

Table IV. Comparison of the FMIA of successfully and unsuccessfully corrected Class II malocclusions

	Successful	*Unsuccessful*
60 and above	14	13
59 and below	26	27

Table V. Comparison of the SNB of successfully and unsuccessfully corrected Class II malocclusions

	Successful	*Unsuccessful*
Below 75	14	23
75-80	20	16
Above 80	6	1

most equally as well as Class II malocclusions with high Frankfort mandibular plane angles.

Finally, the sample was divided by the value of the SNB angle as seen in Table V. This grouping did reveal some minor trends similar to the FMA groupings. The trends that were observed were that there were more unsuccessful corrections toward the lower SNB angle cases. However, the observations were only trends, inclinations, proclivities; there was no conclusive evidence, precisely predictive in nature, for the correction of a given Class II malocclusion.

The preceding data confirmed the suspicion that these key cephalometric indicators separately were of little predictive value. Therefore the criteria were combined in anticipation that their collective value might be more reliable in predicting success of failure of a given Class II orthodontic treatment. An index was formulated in such a manner that values could be numerically added and then expressed as a single mathematical entity, the Probability Index.

The angular numerical difference that existed between these cephalometric criteria made it necessary to assign an arithmetic factor to the variance

Table VI. The probability index

	Point value	*Cephalometric value*	*Probability index*
FMA 20-30	5		
ANB 6 or less	15		
FMIA 60 or more	2		
OCC PL 7 or less	3		
SNB 80 or more	5		
		Total	

Table VII. The probability index

	Point value	*Cephalometric value*	*Probability index*
FMA 20-30	5	35	25
ANB 6 or less	15	8	30
FMIA 60 or more	2	54	12
OCC PL 7 or less	3	10	9
SNB 80 or more	5	75	25
		Total	101

Table VIII. The PI distribution of successfully corrected difficult Class II malocclusions

	Before treatment	*After treatment*
Over 100	0 cases	0 cases
90-99	3 cases	0 cases
80-89	3 cases	1 cases
70-79	6 cases	2 cases
60-69	6 cases	3 cases
50-59	7 cases	4 cases
40-49	3 cases	6 cases
30-39	6 cases	4 cases
20-29	3 cases	10 cases
10-20	2 cases	9 cases
0-10	1 cases	1 cases

in degrees so that the relative importance of each criteria would be correctly interrelated or weighted in importance. The mathematic factor shown in Table VI was determined by considering the anatomic importance of each cephalometric angle and the arithmetic value of that angle. The ranges of successful correctability appear following each cephalometric crtieria. When the key cephalometric angles of a given Class II malocclusion fall within these limits, that Class II malocclusion falls within the favorable range for successful Class II correction. The amount by which the key cephalometric angles of a given Class II malocclusion fall outside these limits will be the varying degree of difficulty encountered in the correction of a given Class II malocclusion.

Table VII shows an example of the method of using the Probability Index for a sample Class II malocclusion. The arithmetic is simple. The FMA of 35° is 5° outside the correctable range. Five degrees multiplied by the point value of 5, gives the Probability Index for the FMA of 25. The other variables are calculated in the same manner and totaled, in this instance, to yield a Probability Index of 101.

PROBABILITY INDEX OF SUCCESSFUL TREATMENTS

This study was composed of a random selection of 40 unsuccessfully corrected difficult Class II malocclusions and 40 successfully corrected difficult Class II malocclusions taken from previous research. Table VIII shows the distribution of the Probability Index in the sample of 40 Class II

Table IX. The PI distribution of successfully corrected difficult Class II malocclusions

Over 100 - 0 cases	
Over 90 - 3 cases	7.5%
Over 80 - 6 cases	15%
Over 70 - 12 cases	30%
Over 60 - 18 cases	45%
Over 50 - 25 cases	62.5%
Over 40 - 28 cases	70%
Over 30 - 34 cases	85%
Over 20 - 37 cases	92.5%

malocclusions that were successfully corrected. It is noteworthy that none of the cases had a Probability Index of greater than 100. Three of the cases had an index of greater than 90 and only six had an index greater than 80.

In Table IX the data appears in a slightly different manner, the Probability Index distribution was expressed in percentages. Only 7.5% of the sample had an index greater than 90, whereas 15% had a Probability Index of greater than 80. In short, 85% of the difficult Class II malocclusions were successfully corrected when the Probability Index was less than 80.

Table X shows the data from a third perspective. The highest pretreatment Probability Index in those Class II malocclusions that were successfully corrected was 95, the lowest was 7. However, the most significant observation was that the average Probability Index of this successfully corrected Class II sample was only 54. It was also of some interest to note the changes that took place in the Probability Index as a result of orthodontic treatment. The pretreatment Probability Index of 95 was corrected to 37, denoting excellent orthodontic treatment. However, the most significant finding here was in the averages. The average Probability Index was reduced by orthodontic treatment from 54 to 35.

PROBABILITY INDEX OF UNSUCCESSFUL TREATMENTS

Table XI shows the Probability Index distribution in the unsuccessfully corrected Class II sample. There were 16 cases greater than 100. In the successfully treated Class II sample there were only three cases greater than 90, compared with 21 in this grouping. In the successful sample there were only six cases greater than 80, compared with 25 cases with a Probability Index of greater than 80 in unsuccessfully treated cases. Table XII shows almost two-thirds of the cases in the unsuccessful

Table X. The probability index of successfully corrected difficult Class II malocclusions

	Before treatment	*After treatment*
High	95 (37)	89 (81)
Low	7 (14)	9 (30)
Average	54.18	35.5

sample had a Probability Index of greater than 80 and more than half had an index of greater than 90. The unsuccessful case with the highest Probability Index was 222 compared with only 95 in the successful sample. The lowest Probability Index in this unsuccessful sample was 46 compared with 7 in the successful sample. By any standards, these differences were profound. Finally, and perhaps most revealing, this sample of unsuccessfully corrected difficult Class II malocclusions had an average Probability Index of 98 compared with only 54 in the successfully corrected sample.

One other distinctive observation was that the average Probability Index in the successful sample was changed by orthodontic treatment from 54 to 35, a 65% correction. In the unsuccessful sample the average pretreatment Probability Index was 98 and the average posttreatment was 96, almost no correction at all as a result of orthodontic treatment. The Probability Index is not only of value in predicting the correctability of a given Class II malocclusion, but might also be of some value in evaluating an orthodontist's performance in Class II orthodontic treatment. Simply stated, the greater the reduction of the Probability Index of a given Class II malocclusion, the better are the treatment methods. Perhaps, through the use of the Probability Index there will be a means by which an objective evaluation of orthodontic treatment results submitted by other orthodontists can be made.

In Table XIII are some comparisons that may help in further evaluating the reliability of the Probability Index. In the successfully corrected sample only six cases (15%) had a Probability Index of greater than 80, whereas in the unsuccessfully corrected Class II sample 25 cases (62.5%) had a Probability Index of greater than 80.

RESULTS

The Probability Index not only indicates the correctability of a Class II malocclusion, and bears some reflection of performance in orthodontic treatment; but perhaps it is also an expression of the growth potential of a given Class II malocclu-

Table XI. The PI distribution of unsuccessfully corrected difficult Class II malocclusions

	Before treatment	*After treatment*
Over 200	1 cases	4 cases
150-199	4 cases	4 cases
125-149	5 cases	3 cases
100-124	6 cases	5 cases
90-99	5 cases	2 cases
80-89	4 cases	2 cases
70-79	4 cases	3 cases
60-69	5 cases	6 cases
50-59	5 cases	2 cases
40-49	1 cases	5 cases
30-39	0 cases	1 cases
20-29	0 cases	2 cases
10-19	0 cases	0 cases
0-9	0 cases	1 cases

Table XII. The PI distribution of unsuccessfully corrected difficult Class II malocclusions

Over 100 - 16 cases	40%
Over 90 - 21 cases	52%
Over 80 - 25 cases	62.5%
Over 70 - 29 cases	75%
Over 60 - 34 cases	85%
Over 50 - 39 cases	97.5%

Table XIII. Comparison of successful and unsuccessful Class II sample

	Successful	*Unsuccessful*
Over 200	0	1
150-199	0	4
125-149	0	5
100-124	0	6
90-99	3	5
80-89	3 = 6	4 = 25

Table XIV. Probability index

Over 100	Impossible prognosis
90-99	Very poor prognosis
80-89	Poor prognosis
70-79	Fair prognosis
60-69	Good prognosis
50 and below	Excellent prognosis

sion. When it is greater than 100, successful correction of a Class II malocclusion is virtually impossible without adjunctive orthognathic surgery.

When the Probability Index (Table XIV) is between 90 and 99, the prognosis is very poor. The treatment plan will be borderline surgery. Successful orthodontic correction of these types of Class II malocclusions will almost certainly require additional extractions. Even then, successful treatment will be elusive.

When the Probability Index is between 80 and 89, the prognosis remains poor, but successful Class II correction is more likely. However, to attain this success it will be of the utmost importance that the orthodontist exercise excellent intrusive force control.

When the Probability Index falls between 70 to 79, Class II correction becomes much easier. However, excellent appliance control is still a prerequisite to excellent orthodontic results.

When the Probability Index falls below 69, prognosis becomes good. Usually a minimum effort will result in an excellent correction of a Class II malocclusion.

CONCLUSIONS

The following points are offered as potential uses of the Probability Index:

1. To aid in identifying those Class II malocclusions severe enough to consider maxillofacial surgery as an adjunct to Class II orthodontic correction.
2. To aid in identifying those very difficult Class II malocclusions that may require alternate treatment methods, such as extraction of the maxillary first or second molars in addition to the extraction of premolars.
3. To aid in predicting more accurately the

treatment time necessary to correct a given Class II malocclusion and to thereby enable an orthodontist to assign a fairer and more appropriate fee.

4. To evaluate previously treated Class II malocclusions for critical review of treatment methods and subsequent revision of these methods to improve Class II treatment procedures.
5. To indicate possible growth potential of a given Class II malocclusion.
6. To evaluate the performance of a clinician in orthodontic treatment.

The Probability Index is far from being proven; this article is only an introduction. Every clinician is invited to test its validity and reliability. The Charles H. Tweed International Foundation will continue to test this index until its reliability has been conclusively proven or disproven. Contingent on the results, it can then either be added to orthodontic diagnosis and treatment planning, or it can be discarded.

REFERENCES

1. Gramling JF. A study of Tweed's Class II correction. Unpublished paper presented to the thirteenth biennial meeting of the Charles H. Tweed International Foundation, Memphis, Tennessee, October 3, 1980.
2. Tweed CH. Indications for the extraction of teeth in orthodontic procedures. AM J ORTHOD ORAL SURG 1944;30: 405-28.
3. Tweed CH. A philosophy of orthodontic treatment. AM J ORTHOD ORAL SURG 1945;31:74-103.
4. Gramling JF. A cephalometric appraisal of the results of orthodontic treatment on one hundred fifty successfully corrected difficult Class II malocclusions. J Charles Tweed Found 1987;15:102-11.
5. Gramling JF. A cephalometric appraisal of the results of orthodontic treatment on fifty-five unsuccessfully corrected difficult Class II malocclusions. J Charles Tweed Found 1987;15:112-24.
6. Tweed CH. The Frankfort-mandibular plane angle in orthodontic diagnosis, classification, treatment planning, and prognosis. AM J ORTHOD 1946;32:175-221.
7. Reidel R. The relation of maxillary structures to cranium in malocclusion and in normal occlusion. Angle Orthod 1952; 22:142-5.
8. Downs WB. The role of cephalometrics in orthodontics case analysis and diagnosis. AM J ORTHOD 1952;38:162-82.
9. Tweed CH. The Frankfort-mandibular incisor angle (FMIA) in orthodontic diagnosis, treatment planning and prognosis. AM J ORTHOD 1954;24:121-69.
10. Reidel R. The relation of maxillary structures to cranium in malocclusion and in normal occlusion. Angle Orthod 1952; 22:142-5.

Reprint requests to:
Dr. James Vaden
308 East First St.
Cookeville, TN 38501