The Tweed-Merrifield Edgewise Appliance: Philosophy, Diagnosis, and Treatment

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Nothing worthwhile ever departs.

HISTORICAL PERSPECTIVE

An obsession for order motivated Edward Hartley Angle (Figure 16-1) to create, in 1888, the Angle System. This system ultimately resulted in the introduction of the edgewise multibanded appliance, the progenitor of all modern appliances. 5 years before Angle's death.

THE ANGLE SYSTEM

Edward Angle, after graduation from dental school in 1878 and before his introduction of the Angle System in 1888, experienced many technical problems and frustrations in treatment that motivated and inspired him to develop a standard appliance. He believed that an orthodontic appliance must have five properties:

1. Simplicity: It must push, pull, and rotate teeth.
2. Stability: It must be fixed to the teeth.
3. Efficiency: It must be based on Newton’s third law of anchorage.
4. Delicacy: It must be accepted by the tissues and it must not cause inflammation and soreness.
5. Inconspicuousness: It must be esthetically acceptable.

Angle designed a standard appliance composed of a specific number of basic components (Figure 16-2). He had these components mass produced so that they could be assembled into a simple, stable, efficient, delicate, and inconspicuous treatment device, without difficulty, in less time and with minimal pain and discomfit to the patient. This universal appliance enabled practitioners to treat more patients at a higher level of excellence and at less cost than they had done previously. In effect, it was the beginning of a relationship between manufacturers, suppliers, and orthodontists that was the Angle System.

THE EDGEWISE APPLIANCE

Two years before he died, with the knowledge born from experience and gained from his other appliance inventions, Angle set out to devise an appliance that not only would overcome past difficulties but also would have a greater chance than did its predecessors.

Figure 16-1
Edward H. Angle.
of treating to “ideals.” He changed the form of the brackets by locating the slot in the center and placing it in a horizontal plane instead of a vertical plane. The arch wire was held in position first by a brass ligature and later by a delicate stainless steel wire ligature. The new edgewise bracket consisted of a rectangular box with three walls within the bracket, 0.022 × 0.028 inch in dimension. The bracket slot opened horizontally (Figure 16-3). This new design provided more accuracy and thus a more efficient torquing mechanism.

Because Angle introduced the edgewise bracket only 2 years before he died, he had little time to teach its manipulation, develop it further, and improve its use—and he knew it.

CHARLES H. TWEED

When Charles H. Tweed graduated from an improvised Angle course given by George Hahn in 1928, he was 33 years old and Angle was 73 (Figure 16-4). Angle was bitterly disappointed by the reception that he had accorded the edgewise appliance. He was infuriated and bitter about the modifications that were being made by several of his graduates (e.g., Spencer Adkinson). To him it was obvious that something had to be done if the edgewise appliance was to survive intact.

Angle decided that an article describing the appliance must be published in Dental Cosmos. Angle asked Tweed
successes and failures. During this 4-year period, he made a most important observation: upright mandibular incisors frequently were related to posttreatment facial balance and successful treatment. To position mandibular incisors upright, he concluded that one must prepare anchorage and extract teeth. He then selected his failures, extracted four first premolar teeth, and retreated the patients. He did this without charging a fee.

In 1936 Tweed delivered to the membership of the Angle Society and subsequently published his first paper on the extraction of teeth for orthodontic malocclusion correction. "Mother" Angle, the editor of the Angle Orthodontist, and a member of the Angle Society, refused to attend the lecture. George Hahn, the man who went out of his way to create the opportunity for Tweed to take the Angle course, criticized him severely. Angle disciples considered Charles Tweed to be a traitor to the greatest man orthodontics had ever known. Tweed was crushed by the response, but he returned home determined to continue his research.

He worked even harder than before. By 1940, he had produced case reports, with four sets of records, of 100 consecutively treated patients, first treated with nonextraction methods and later in with extraction. He managed to get himself on the program of the next meeting of the Angle Society in Chicago, where he would present a paper and display his case reports.

Dr. Strang, one of Angle’s students in the early years, described the event this way:

I noted that Dr. Charles Tweed was scheduled to be on the program of the meeting in Chicago. I planned to be there with the objective of having him for violating Dr. Angle’s sacred principle of non-extraction in treatment.

Previous to reading his paper, Dr. Tweed had placed on tables before and after case and photographs of one hundred consecutively treated patients. The results in all of these one hundred patients were magnificent and beyond criticism.

Dr. Tweed read his well-written and illustrated paper. He explained his objective of keeping the teeth over basal bone, which made it necessary to extract teeth in many patients; however, it did produce stable results. Then he sat down. There was no applause.

The room filled with heated demands from the floor. For at least an hour. Charlie got the worst tongue-lashing that you can possibly imagine and not one word of praise for the beautiful results of treatment. Here was a student of Dr. Angle’s violating the most fixed and rigid rule in his instruction—never extract teeth.

During all this vicious attack, my mind took a complete turnover. I could visualize nothing but that marvelous exhibit of treated cases. Not one individual in the room had complimented the essayist. They were all ripping him to pieces for extracting teeth. Finally, I obtained the floor and complimented and defended him to the best of my ability. When I sat down, I, too, took a tongue-lashing that compared very favorably with the one Charlie had just received. Subsequently, I took his course, and practiced, taught and published his techniques in my textbook.
Tweed’s many contributions to the specialty established a benchmark in orthodontic thought and treatment. Most notable among his many contributions were the following:

1. He emphasized the four objectives of orthodontic treatment with emphasis and concern for facial esthetics.
2. He developed the concept of uprighting teeth over basal bone with emphasis on the mandibular incisors.
3. He made the extraction of teeth for orthodontic correction acceptable and popularized the extraction of the first premolars.
4. He enhanced the clinical application of cephalometrics.
5. He developed the diagnostic facial triangle to make cephalometrics a diagnostic tool and a guide in treatment and in the evaluation of treatment results (Figure 16-5).
6. He developed a concept of orderly treatment procedures and introduced anchorage preparation as a major step in treatment.
7. He developed a fundamentally sound and consistent preorthodontic guidance program, using and popularizing serial extraction of primary and permanent teeth.

In addition to his many clinical contributions to the specialty, Tweed gave guidance, inspiration, and leadership to more orthodontists in the world than anyone else of his time. Because of Charles Tweed, his skill, and his determination, the edgewise appliance became universally popular, and the practice of clinical orthodontics became a health service requested by the public.

Angle gave orthodontics the edgewise bracket, but Tweed gave the specialty the appliance. Tweed was considered the premier edgewise orthodontist of his day. Many who admired his results wished to learn his techniques. The orthodontic world journeyed to Tucson, Arizona, to take Tweed’s course and learn his method of treatment with the edgewise appliance. The Tweed Philosophy was born.

Charles Tweed, one of orthodontics’ most brilliant innovators, kept his promise to his mentor, Edward Hartley Angle. He devoted 42 years of his life, from 1928 until his death on January 11, 1970, to the advancement of the edgewise appliance.

LEVERN MERRIFIELD

In 1960 Tweed selected one of his most outstanding students, Levern Merrifield, from Ponca City, Oklahoma, to continue his work on the edgewise appliance and be the codirector of his course with him (Figure 16-6). Merrifield took Tweed’s course in 1953 and became a member of Tweed’s staff in 1955. He became the codirector at the time of Tweed’s death in 1970. Merrifield devoted the remaining 45 years of his life to the study of orthodontic diagnosis and the use of the edgewise appliance. Merrifield’s contributions have been popularized. They include the following:

- **Diagnostic concepts**
  1. The fundamental concept of dimensions of the dentition

Figure 16-5

Tweed’s diagnostic facial triangle. FMA, Frankfort mandibular plane angle; FMIA, Frankfort mandibular incisor axis angle; IMPA, lower incisor mandibular plane angle.

Figure 16-6

Levern Merrifield.
2. Dimensions of the lower face
3. Total space analysis
4. Guidelines for space management decisions to achieve the following:
   a. Facilitate maximal orthodontic correction
   b. Define areas of skeletal, facial, and dental disharmony

Treatment concepts
5. Sequential control during treatment
6. Sequential tooth movement
7. Sequential mandibular anchorage preparation
8. The organization of treatment into four orderly steps that have specific objectives

Merrifield's innovations in diagnosis and his experience in the use of the edgewise appliance have improved on Tweed's contributions and concepts to give the modern orthodontist a more accurate, reliable, precise, efficient, and practical protocol of diagnosis and treatment. Adherence to this protocol allows the clinician to do the following:

1. Define objectives for the face, dentition, and skeletal pattern.
2. Properly diagnose the malocclusion.
3. Use the edgewise appliance to reach the predetermined objectives efficiently.

DIMENSIONS OF THE DENTITION

The clinical practice of orthodontics has always been based on the various dimensions of the dentition: height, width, and length (vertical, transverse, and sagittal). These dimensions allow the teeth to be moved in six directions: mesially, distally, facially, lingually, intruded, and extruded. All of these movements, which are accomplished routinely with orthodontic appliances, are limited and restricted by the physical environment of bone, muscle, and soft tissue, all of which exert an influence on the teeth and jaws.

Since the beginning of the orthodontic specialty, an effort has been made to determine the extreme limits of this environment. Each engineering change in appliance fabrication appears to bring about a new challenge to the physical limitations of the dentition's environment. Dimensions of the dentition include four basic premises provided that the musculature is normal:

Promise 1: An anterior limit exists. The teeth must not be placed far forward, off basal bone. If the teeth are too far forward, all the aforementioned objectives of treatment are compromised.

Promise 2: A posterior limit exists. Teeth can be positioned and/or impacted into the area behind the mandibular first molar in the mandibular arch even as they can be moved too far forward off basal bone.

Promise 3: A lateral limit exists. If the teeth are moved buccally into the masseter and buccinator muscles, relapse is likely to result over the long term.

Promise 4: A vertical limit exists. Vertical expansion is disastrous to facial balance and harmony in the sagittal plane, except in deep-bite cases.

In summary, orthodontists must recognize the limitations of the dental environment and design treatment to conform to these dimensions when normal muscle balance exists.

DIFFERENTIAL DIAGNOSIS

Merrifield, in his effort to establish a sound diagnostic basis for his directional force treatment using multibanded mechanotherapy, introduced diagnostic analyses that allow clinicians to determine (1) whether and when extractions are necessary and (2) if extractions are indicated, which teeth should be removed. His work enabled the clinician to arrive at a differential diagnosis instead of treating all extraction problems by the removal of four first premolars as did Dr. Tweed.

Merrifield's diagnostic philosophy can be outlined as follows:

1. Recognize and treat within the dimensions of the dentition. This means nonexpansion of malocclusions when normal muscular balance exists.
2. Recognize the dimensions of the lower face and treat for maximum facial harmony and balance.
3. Recognize and understand the skeletal pattern. Diagnose and treat in harmony with normal growth and developmental patterns and optimize the less than normal pattern. After the major areas of disharmony are identified, all necessary and practical means should be expended to correct the problem.

Facial Disharmony

A study of the face and its balance or lack of balance must be the first concern during a differential diagnosis. The clinician must have an intuitive concept of a balanced face. Essentially three factors influence facial balance or lack thereof: (1) the positions of the teeth, (2) the skeletal pattern, and (3) the soft tissue thickness.

Facial balance is affected by marked protrusion and crowding of the teeth. The lips are supported by the maxillary incisor teeth. The upper lip rests on the upper two thirds of the labial surface of the maxillary incisors, and the lower lip is supported by the lower one third of the labial surface of the maxillary incisors. Thus lip protrusion is a reflection of the amount of maxillary incisor protrusion. Maxillary incisor position is related directly, of course, to the position of the mandibular incisors. Protruded teeth cause facial imbalance.

Facial disharmonies are often the result of abnormal skeletal relationships. The clinician must understand the skeletal pattern and have the ability to compensate for abnormal skeletal relationships by changing the positions of the teeth. The Frankfort mandibular plane
angle (FMA) is a skeletal angular value that is crucial in differential diagnosis. Dental compensation for a high FMA requires additional uprighting of flared mandibular incisors. Lower facial balance can be improved dramatically by using this knowledge.

Conversely, dental compensation for a low FMA requires less mandibular incisor uprighting. Decisions regarding tooth position objectives must be made after a thorough study of the skeletal pattern.

Facial disharmonies that are not the result of skeletal or dental distortion are generally the result of poor soft tissue distribution. Disharmony needs to be identified during differential diagnosis so that crucial dental compensations can be planned. The millimetric measurements of total chin thickness and upper lip thickness are essential components in any study of facial balance. Upper lip thickness is measured from the greatest curvature of the labial surface of the maxillary central incisor to the vermilion border of the upper lip (Figure 16-7). The total chin thickness is measured horizontally from the NB line extended to soft tissue pogonion. Total chin thickness should equal upper lip thickness. If total chin thickness is less than upper lip thickness, the anterior teeth must be positioned upright further to facilitate a more balanced facial profile because lip retraction follows tooth retraction.

Careful consideration of the positions of the teeth, the skeletal pattern, and the soft tissue overlay will give crucial information about the face and enable the clinician to determine whether dental compensations will improve facial balance. Before initiating tooth movement, the clinician must understand clearly its impact on the overlying soft tissue.

The profile line and its relationship to facial structures and the Frankfort plane can be used to give the orthodontic practitioner an idea of lip procumbency. If the profile line lies outside the nose, a protrusion exists (Figure 16-8). When facial balance is present, the ideal relationship of profile line is to be tangent to the chin, and the vermilion border of both lips and should lie in the anterior one third of the nose (Figure 16-9). For centuries, the premise has been that this type of relationship
of the profile line to the lips, chin, and nose results in a pleasing and balanced appearance.

Similarly, on frontal view the face should be balanced. The vermilion border of the lower lip should bisect the distance between the bottom of the chin and the ala of the nose. The vermilion border of the upper lip also should bisect the distance from the vermilion border of the lower lip to the ala of the nose. These relationships are universally accepted orthodontic standards for facial balance and harmony.

Several cephalometric angles quantify facial balance. Two that have been found to be useful are the Z angle and the Frankfort mandibular incisor axis angle (FMIA) (Figure 16-10).

**Z angle**

The chin/lip soft tissue profile line relationship to the Frankfort horizontal plane quantifies facial balance (Figure 16-10). The normal range is 70 to 80 degrees.24 The ideal value is 75 to 78 degrees, depending on age and gender. This angle was developed to define facial aesthetics further and is an adjunct to the FMIA. The Z angle is more indicative of the soft tissue profile than the FMIA and is responsive to maxillary incisor position. Maxillary incisor retraction of 4 mm allows 4 mm of lower lip retraction and about 3 mm of upper lip response. Horizontal mandibular repositioning also affects this value. Vertical facial height increase, anterior and posterior, can influence the Z angle.

The Z angle quantifies the combined abnormalities in the values of the FMA, FMIA, and soft tissue thickness and all have a direct bearing on facial balance. The Z angle gives immediate guidance relative to anterior tooth repositioning. If the patient has a normal FMA of 25 degrees, a normal FMIA of 68 degrees, and good soft tissue overlay distribution, the Z angle value should be about 78 degrees. If any of the three components is not within its optimal range, differentiation can be made to determine which values are not optimal and why. Tooth positions can be altered subsequently to favorably influence facial balance.

Frankfort mandibular incisor angle (FMIA)

Tweed established a standard of 68 degrees for individuals with an FMA of 22 to 28 degrees. The standard should be 65 degrees if the FMA is 30 degrees or more, and the FMIA will increase if the FMA is lower. Tweed believed that this value was significant in establishing balance and harmony of the lower face (Figure 16-10).

**Cranial Disharmony**

An analytic observation of the skeletal pattern is an integral part of any diagnosis. A careful cranial analysis must include study and an understanding of the following information, which can be gleaned from a cephalogram (Figures 16-11 and 16-12).

**Skeletal analysis factors**

Frankfort Mandibular Plane Angle (FMA). The FMA is probably the most significant value for skeletal analysis because it defines the direction of lower facial growth in the horizontal and vertical dimensions. The standard or normal range of 22 to 28 degrees for this value projects a skeletal pattern with normal growth direction. An FMA greater than the normal range indicates excessive vertical growth, and an FMA less than the normal range indicates deficient vertical growth.

Incisor Mandibular Plane Angle (IMPA). The IMPA defines the axial inclination of the mandibular incisor in relation to the mandibular plane. The IMPA is a good guide to use in maintaining or positioning these teeth in their relationship to basal bone. The standard of 88 degrees indicates an upright position and with a normal FMA reflects optimal balance and harmony of the lower facial profile. If the FMA is above normal, the orthodontist must compensate by further uprighting the mandibular incisors. If the FMA is below the normal range, compensation can be made by leaving the mandibular incisors at their pretreatment position or in rare instances by positioning them more to the labial. Labial inclination of the mandibular incisors generally is limited to their original inclination if the patient has normal muscular balance.

Sella-Nasion-Subspinale Angle (SNA). The SNA angle indicates the relative horizontal position of the maxilla to cranial base. The range at the termination of growth is 80 to 84 degrees for a white population sample.
Sella-Nasion-Supramentale Angle (SNB). The SNB angle expresses the horizontal relationship of the mandible to the cranial base. A range of 78 to 82 degrees indicates a normal horizontal mandibular position. If the value is less than 74 degrees and a large maxillomandibular discrepancy exists, orthognathic surgery should be considered as an adjunct to orthodontic treatment. The same concern should be accorded to a value of more than 84 degrees.

Subspinale-Nasion-Supramentale Angle (ANB). The normal range for the ANB angle is 1 to 5 degrees. This value expresses a favorable horizontal relationship of the maxilla to the mandible. Class II malocclusions become proportionally more difficult with higher ANB angles. A patient with an ANB greater than 10 degrees usually will require surgery as an adjunct to proper treatment. The negative ANB angle is even more indicative of facial disproportion in the horizontal dimension. An ANB angle of -3 degrees or more, when the mandible is in its centric relation, indicates a possibility of surgical assistance in Class III orthodontic correction.

AO-BO. The AO-BO relationship indicates the horizontal relationship of the maxilla to the mandible and
is perhaps more sensitive to malrelationships than the ANB angle because it is measured at the occlusal plane. Orthodontic treatment becomes more difficult when the AO-BO is greater than the normal range of 0 to 4 mm. The AO-BO changes in direct proportion to the occlusal plane angle.

**Occlusal Plane.** The occlusal plane angle expresses a dento-skeletal relationship of the occlusal plane to the Frankfort horizontal plane. A range of 8 to 12 degrees is normal with variations of about 2 degrees between males and females. The angle for the female averages about 9 degrees and for the male about 11 degrees. Values greater or less than the normal range indicate more difficulty in treatment. In most orthodontic corrections the original value should be maintained or decreased. An increase in the occlusal plane angle during treatment indicates a loss of control. An increase is usually unstable because the occlusal plane is determined by muscular balance, primarily the muscles of mastication. The occlusal plane angle frequently returns to its pretreatment value when it is increased, resulting in a detrimental relapse of the "corrected" interdentai relationship.

**Posterior Facial Height.** Posterior facial height (PFH) is a linear millimeter measurement of ramus height from articular to the mandibular plane tangent to the posterior border of the ramus. The value is related to facial form, vertically and horizontally. An increase in ramus height is essential for downward and forward mandibular response. The relationship of PFH to anterior facial height determines the FMA and lower facial proportion. In the growing child with a Class II malocclusion, ramal growth change and its relationship to anterior facial height in proportion and in volume is crucial.

**Anterior Facial Height.** The anterior facial height (AFH) is a linear measurement in millimeters of the vertical distance between the palatal plane and menton. The line is perpendicular to the palatal plane. A value of about 65 mm for a 12-year-old individual indicates a normal anterior facial height. This vertical value must be monitored carefully if it is more than 5 mm more or less than normal. In Class II malocclusion correction, limiting an increase in AFH is essential and is accomplished by controlling maxillary and mandibular molar expansion and by using an anterior high-pull force on the maxilla.

**Facial Height Index.** Andre Horn studied the relationship of AFH to PFH. After developing the facial height index, he found that normal PFH is 0.69, or 69% of AFH. The normal range of PFH to AFH is 0.65 to 0.75. If the value is less than or greater than this range, the malocclusion is more complex and the orthodontist will encounter difficulty in correction. An index of 0.80 is severe and indicates a flat FMA malocclusion caused by too much posterior ramal growth or too little anterior growth. As the index approaches 0.60, the skeletal pattern demonstrates too little posterior height or too much anterior height.

**Facial Height Change Ratio.** The facial height change ratio is valuable in the evaluation of treatment interval changes. A ratio of 2 times as much PFH increase as AFH increase during treatment is ideal for the correction of Class II, Division 1 and dentoalveolar protrusion malocclusions. However, even more important is the volume of change. For example, a 6-mm PFH increase with a 3-mm AFH increase is much more beneficial than a 2-mm PFH increase coupled with a 1-mm AFH increase even though both values reflect a 2:1 ratio.

Radziemski, Gebeck and Merrifield, Issacson, Pearson, and Schudy have described the important relationship between vertical dimension control and successful treatment of Class II malocclusions. After an evaluation of successfully and unsuccessfully treated Class II malocclusions, Merrifield and Gebeck concluded that successfully treated patients exhibited favorable mandibular changes. These changes occurred primarily because AFH was controlled and PFH was increased. Unsuccessful treatment results were more likely to occur in patients in whom an increase was observed in AFH but not in PFH. Merrifield and Gebeck reported a 2:1 ratio of increase in PFH to AFH in their sample of successfully treated Class II malocclusions; that is, PFH increased on the average twice as much as AFH.

**Craniofacial analysis**

For a period of about 15 years, until his untimely death in June 1993, Jim Gramling of Jonesboro, Arkansas, was the research director for the Charles H. Tweed Foundation. During those years, Gramling compiled a large sample of successfully and unsuccessfully treated Class II malocclusions.

The results of these studies of unsuccessful and successful treatment were compared and can be seen in Table 16-1. In the successful sample, FMA was controlled, FMIA was increased, and IMPA was reduced. In the unsuccessful sample, FMA increased, FMIA remained the same or decreased a minimal amount, and IMPA increased or remained the same. Not as much Z angle increase occurred in the unsuccessful sample as occurred in the successful sample. SNA reduction was similar, but AO-BO reduction for the unsuccessful sample was not as good as for the successful sample. Y axis values and SBN values remained the same for both samples. By studying the collected data from these two samples, in unsuccessful Class II treatment the mandibular incisor position was not corrected. If it was corrected, the correction was compromised subsequently by excessive, unreciprocated use of Class II elastics in an attempt to establish the proper anteroposterior maxillomandibular dental relationships.
### Table 16-1: A Comparison of Gramling's Studies of Successful and Unsuccessful Class II Correction

<table>
<thead>
<tr>
<th></th>
<th>Successful Pretreatment</th>
<th>Successful Posttreatment</th>
<th>Unsuccessful Pretreatment</th>
<th>Unsuccessful Posttreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMA</td>
<td>27</td>
<td>27</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>FMIA</td>
<td>58</td>
<td>63</td>
<td>56</td>
<td>55</td>
</tr>
<tr>
<td>IMPA</td>
<td>95</td>
<td>90</td>
<td>95</td>
<td>97</td>
</tr>
<tr>
<td>Z angle</td>
<td>66</td>
<td>75</td>
<td>62</td>
<td>69</td>
</tr>
<tr>
<td>Y axis</td>
<td>62</td>
<td>62</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>SNA</td>
<td>82</td>
<td>79</td>
<td>81</td>
<td>79</td>
</tr>
<tr>
<td>SNB</td>
<td>76</td>
<td>76</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>ANB</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>AO-BO</td>
<td>4</td>
<td>-1</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>

In 1989 Gramling studied a different sample of 40 successful and 40 unsuccessful Class II malocclusion corrections. After this study, he revised only one of the five premises of the probability index. He changed the successful FMA range from 18 to 35 degrees to 22 to 28 degrees (Table 16-3).

### Table 16-2: The Probability Index Variables with the Statistically Computed Difficulty Factors

<table>
<thead>
<tr>
<th>Cephalometric Angle</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMA</td>
<td>5 points</td>
</tr>
<tr>
<td>ANB</td>
<td>15 points</td>
</tr>
<tr>
<td>FMIA</td>
<td>2 points</td>
</tr>
<tr>
<td>Occlusal plane</td>
<td>3 points</td>
</tr>
<tr>
<td>SNB</td>
<td>5 points</td>
</tr>
</tbody>
</table>

Note: This was Gramling's initial attempt at a probability index.

From the background of evidence gathered from these studies, Gramling formulated a probability index for three specific purposes:
1. To augment diagnostic procedures
2. To guide treatment procedures
3. To predict possible treatment success or failure

Gramling's probability index was based on the premise that control of the FMA, ANB, FMIA, occlusal plane, and SNB were the keys to the success or failure of orthodontic correction of a Class II malocclusion. The probability index suggested that the following pretreatment conditions might be necessary for Class II treatment success:
1. FMA should be 18 to 35 degrees.
2. ANB should be 6 degrees or less.
3. FMIA should be greater than 60 degrees.
4. Occlusal plane should be 7 degrees or less.
5. SNB should be 80 degrees or more.

Gramling statistically established a difficulty factor and assigned a specific number of points to each variable (Table 16-2).

Using information from the previously described clinical research, the craniofacial analysis (Table 16-4), an integral component of the differential diagnostic analysis system, was developed. Each of the six cephalometric values used has been determined to have significant merit. The interrelationship of each of the values has been weighted statistically in relationship to its individual 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.

The FMA, the AFH/PFH ratio, and the occlusal plane to Frankfort angle are significant when used as a group. These values make up the vertical component of the craniofacial analysis. The vertical skeletal pattern can be a problem of excessive AFH in the presence of a decreased PFH, or conversely, a problem of excessive PFH and a decreased AFH. If facial height, anterior or posterior, is out of proportion, correction of the malocclusion is most difficult and one must take great care with treatment procedures so that the vertical disharmonies do not significantly worsen.

The horizontal skeletal component of the craniofacial analysis is composed of the SNB and the ANB. A high ANB caused by a low SNB makes the horizontal skeletal disharmony much more difficult to manage than if the high ANB were caused by an excessive SNA. The low SNB requires a treatment compromise or, if a more ideal result is desired, orthognathic surgery.

The previously described Z angle value is the only non-skeletal measurement in the craniofacial analysis. The Z angle was included because it is a facial indicator of cranial imbalance.
### TABLE 16-3 The Probability Index after the Pretreatment Range for FMA Was Adjusted Downward to 22 to 28 Degrees

<table>
<thead>
<tr>
<th>Point Value</th>
<th>Cephalometric Value</th>
<th>Probability Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMA 22 to 28 degrees</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>ANB 6 degrees or less</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>FMAA 60 degrees or more</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Occlusal plane 7 degrees or less</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>SNB 80 degrees or more</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 16-4 Craniofacial Analysis

<table>
<thead>
<tr>
<th>Normal Range</th>
<th>Cephalometric Value</th>
<th>Difficulty Factor</th>
<th>Difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMA 22 to 28 degrees</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANB 1 to 5 degrees</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angle 70 to 80 degrees</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occlusal plane 8 to 12 degrees</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SNB 78 to 82 degrees</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FH (PFH-AFH) 0.65 to 0.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Craniofacial difficulty total</td>
<td></td>
<td></td>
<td></td>
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</table>

### TABLE 16-5 Total Space Analysis

<table>
<thead>
<tr>
<th>Area</th>
<th>Value</th>
<th>Difficulty Factor</th>
<th>Difficulty</th>
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</thead>
<tbody>
<tr>
<td>Anterior</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Tooth arch discrepancy</td>
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<tr>
<td>Head film discrepancy</td>
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<tr>
<td>Total</td>
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<td></td>
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<tr>
<td>Midarch</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total arch discrepancy</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Curve of Spee</td>
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<td></td>
<td></td>
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<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occlusal disharmony (Class II or Class III)</td>
<td></td>
<td></td>
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<tr>
<td>Posterior</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Tooth arch discrepancy</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Expected increase (-)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td></td>
<td>Space analysis difficulty total</td>
<td></td>
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</tbody>
</table>

### Dental Disharmony

Total dentition space analysis

Along with a consideration of the face and the skeletal pattern, the orthodontist must consider the dentition (Table 16-5). Total space analysis as described by Merrifield is divided into three parts: anterior, midarch, and posterior. This division is made for two reasons: (1) simplicity in identifying the area of space deficit or space surplus and (2) accuracy in differential diagnosis.
Anterior space analysis

Anterior space analysis includes the measurement in millimeters of the space available in the mandibular arch from canine to canine and a measurement of the mesiodistal dimension of each of the six anterior teeth. The difference is referred to as a surplus or deficit. The Tweed diagnostic facial triangle is used to analyze this area further. Cephalometric discrepancy is defined as the amount of space required to upright the mandibular incisors for optimum facial balance. This value is added to the anterior space measurement.

The sum of the anterior tooth arch surplus or deficit and the cephalometric discrepancy is referred to as the anterior discrepancy. Each of these values in the anterior discrepancy calculation has been given a difficulty factor so that an anterior space analysis difficulty value can be calculated.

Midarch space analysis

The midarch area includes the mandibular first molars and the first and second premolars. Careful analysis of this area may show mesially inclined first molars, rotations, spaces, deep curve of Spee, crossbites, missing teeth, habit abnormalities, blocked-out teeth, tooth size discrepancies, and occlusal discrepancies. The midarch is an important area of the dentition. Careful measurement of the space from the distal of the canine to the distal of the first molar should be recorded as available midarch space. An equally accurate measurement of the mesiodistal width of the first premolar, the second premolar, and the first molar also must be recorded. To this is added the space required to level the curve of Spee. From these measurements, the orthodontist can determine the space deficit or surplus in this area.

Occlusal disorganization, a Class II or III buccal segment relationship, though not a part of the actual midarch space analysis, must be measured because an occlusal disorganization adds great deal to the difficulty of correction of any malocclusion and requires careful treatment strategy and space management.

Occlusal disorganization is measured by articulating the casts and by using the maxillary first premolar cusp and its relationship to the mandibular first premolar/second premolar embrasure as a reference. Measure mesially or distally from the maxillary first premolar buccal cusp to the embrasure between the mandibular first and second premolars. This measurement is made on both sides and then is averaged to determine the occlusal disorganization. The difficulty factor for occlusal disorganization is "2," so the averaged disorganization is doubled and added to the midarch difficulty because it has to be corrected by moving teeth that are in the midarch area of the dentition.

Posterior space analysis

The posterior dentition area is of great importance. The dentition has a posterior limit. Regardless of age, this posterior limit appears to be the anterior border of the ramus. The required space in the posterior space analysis is the mesiodistal width of the second molars and the third molars in the mandibular arch. The available space is more difficult to ascertain in the immature patient. The space is a linear measurement in millimeters of the space distal to the mandibular first molar. The measurement is made from the distal of the mandibular first molar to the anterior border of the ramus along the occlusal plane. The posterior limit is recognized as being 2 to 3 mm distal to the anterior border of the ramus because of the lingual shelf that exists to accommodate the mandibular molars. However, these teeth on the lingual shelf are not generally in good functional occlusion. An estimate of posterior arch length increase based on age and gender is added to this value.

Certain more unpredictable variables must be considered in estimating the increase in posterior available space. These variables are the following:

1. Rate of mesioocclusal migration of the mandibular first molar
2. Rate of resorption of the anterior border of the ramus
3. Time of cessation of molar migration
4. Time of cessation of ramus resorption
5. Gender
6. Age

A review of the literature revealed that the consensus of researchers suggests that 3 mm per year of increase occurs in the posterior denture area until age 12 for girls and age 16 for boys. This is an increase of 1.5 mm per year on each side after the full eruption of the first molars. In the mature patient (girls beyond 15 years and boys beyond 16 years), a measurement from the distal of the first molar to the anterior border of the ramus at the occlusal plane is a valuable determination of the space available in the posterior area. This measurement is important in diagnosis and treatment planning to know whether a surplus or deficit of space exists in this area.

To create a posterior discrepancy while making adjustments in other areas such as the midarch or anterior area is not prudent. Equally imprudent is not to use a posterior space surplus to help alleviate midarch and anterior deficits. The most easily recognizable symptom of a posterior space deficit in the young patient is the late eruption of the second molar. If space is not available for this tooth by the age of its normal eruption, it should be obvious that a posterior space problem exists. A good cephalogram immediately can confirm a clinical observation by using the previously mentioned guidelines. The posterior space analysis surplus or deficit has been given a low difficulty factor of 0.5 because a posterior space deficit can be resolved easily by third molar removal.

Differential Diagnostic Analysis System

The two diagnostic tools that have been described, the craniofacial analysis and the total dentition space analysis, used together, make up the differential diagnostic
analysis system (Table 16-6). Use of this diagnostic methodology will significantly improve the clinician’s ability to diagnose, plan, and execute treatment. The sum of the craniofacial difficulty and the total dentition space analysis difficulty is called total difficulty. This value will give the clinician a quantitative method of evaluating the difficulty of correction of each malocclusion. The analysis identifies the specific areas of major disharmony (i.e., facial, skeletal, and dental) and gives guidance for treatment strategy.

Other factors such as habit evaluation, joint health, muscle balance, dental or skeletal malrelationships, and the other cephalometric values must be duly noted, evaluated by the orthodontist, and factored into any diagnosis. The orthodontist also must evaluate the patient’s motivation and desire for orthodontic correction.

The range of values for the total difficulty that have been found to be most appropriate when malocclusion correction difficulty is studied are as follows: mild, 0 to 60; moderate, 60 to 120; and severe, more than 120.

**TWEEDE-MERRIFIELD EDGewise APPLIANCEx**

**Brackets and Tubes**

An appliance is an instrument used to achieve orthodontic goals. As Angle stressed, an appliance must have certain characteristics: simplicity, efficiency, and comfort. An appliance also must be hygienic, esthetic, and above all have a wide range of versatility. The neutral

<table>
<thead>
<tr>
<th>Craniofacial Analysis</th>
<th>Cephalometric Value</th>
<th>Difficulty Factor</th>
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<tr>
<td>Normal Range</td>
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<tr>
<td>FMA 22 to 28 degrees</td>
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</tr>
<tr>
<td>ANB 1 to 5 degrees</td>
<td></td>
<td>15</td>
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</tr>
<tr>
<td>Z angle 70 to 80 degrees</td>
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<td>2</td>
<td></td>
</tr>
<tr>
<td>Occlusal plane 8 to 12 degrees</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>SNA 78 to 82 degrees</td>
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<td>5</td>
<td></td>
</tr>
<tr>
<td>PFA [PFF-AFH] 0.65 to 0.75</td>
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<td>Craniofacial difficulty total</td>
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<table>
<thead>
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<th>Total Space Analysis</th>
<th>Value</th>
<th>Difficulty Factor</th>
<th>Difficulty</th>
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</thead>
<tbody>
<tr>
<td>Anterior</td>
<td></td>
<td>1.5</td>
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</tr>
<tr>
<td>Tooth arch discrepancy</td>
<td></td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Head film discrepancy</td>
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<tr>
<td>Total</td>
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<td></td>
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</tr>
<tr>
<td>Midarch</td>
<td></td>
<td>1.0</td>
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<tr>
<td>Tooth arch discrepancy</td>
<td></td>
<td>1.0</td>
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</tr>
<tr>
<td>Curve of Spee</td>
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</tr>
<tr>
<td>Total</td>
<td></td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Occlusal disharmony</td>
<td></td>
<td>2.0</td>
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</tr>
<tr>
<td>(Class II or Class III)</td>
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</table>

| Posterior             |       | 0.5              |            |
| Tooth arch discrepancy |       |                  |            |
| Expected increase (-) |       |                  |            |
| Total                |       |                  |            |
| Space analysis total  |       |                  |            |
| Craniofacial difficulty total | |                  |            |
| Space analysis difficulty total | |                  |            |
| Total difficulty     |       |                  |            |
0.022 slot edgewise appliance consists of posterior bands and anterior mesh pads with single, double-width 0.022 brackets on the six anterior teeth; intermediate single-width brackets on premolar bands; twin brackets on first molar bands; and heavy edgewise 0.022 tubes with mesial hooks on second molar bands (Figure 16-13). The bands also have lingual hooks attached to the molars and on the premolars. Lingual clamps increase versatility and are especially necessary to correct and control rotations. Each of the brackets and tubes is placed at a right angle to the long axis of the tooth. The brackets are positioned precisely in relation to the incisal edges of the incisor teeth and the cusps of the remaining teeth. No tips, torque, or any variations in thickness are present in the bracket or the neutral slot. A slot size of 0.022 allows the clinician to use a multiplicity of arch wire dimensions.

Arch Wires

Resilient edgewise arch wire is used with the Tweed-Merrifield 0.022-inch edgewise appliance. The dimensions (in inches) of the wire commonly used are 0.017 × 0.022, 0.018 × 0.025, 0.021 × 0.025, 0.020 × 0.025, and 0.0215 × 0.028. These wire dimensions give a great range of versatility with the 0.022 × 0.028 bracket slot and allow the sequential application of forces as needed for various treatment objectives. The objective is to enhance tooth movement and control with the proper edgewise arch wire.

First-, Second-, and Third-Order Bends and Their Interaction

Knowledge of the action, interaction, and reaction of teeth to bends in the arch wire is crucial to the use of any orthodontic appliance. Such knowledge is fundamental and drastically affects clinical results.

First-order bends

The action and reaction of first-order bends affect expansion or contraction. These actions are monitored most easily and are used routinely to move individual teeth. The interaction of the bends can affect the third-order position of the teeth if expansion forces are used.

Second-order bends

Second-order bends in the posterior segment of the mandibular arch wire are antagonistic to the teeth in the anterior segment. Without excellent directional control and a careful application of these second-order forces in a sequential manner, vertical control of the anterior teeth will be lost.

Second-order bends in the posterior segment of the mandibular arch wire also negatively affect the third-order position of the mandibular anterior teeth. These teeth generally require lingual crown torque. Posterior tipping bends apply labial crown torque force to the incisors. This factor must be given careful consideration in arch fabrication and force application.

In the maxillary arch, second-order bends (an exaggerated curve of Spee) in the posterior segments are generally desirable or complementary to the teeth in the anterior segment. The reaction to the tipping force intrudes the maxillary incisors and gives a lingual root torque effect to these teeth. This is generally positive of complementary to treatment objectives.

Third-order bends

Third-order bend reaction in the mandibular arch wire is complementary to all the teeth if properly placed. The objective is to have some degree of lingual crown torque on all the mandibular teeth. The posterior and anterior segments work together in action, reaction, and interaction. The ideal third-order bends in the mandibular...
arch wire are as follows: incisors, 7 degrees; canines and first premolars 12 degrees, and second premolars and molars, 20 degrees.

Conversely, third-order bends in the maxillary arch wire are antagonistic. The anterior segment needs no torque (0 degrees) or slight lingual root torque, and the posterior segment needs lingual crown torque: canines and first premolars (7 degrees) and second premolars and molars (12 degrees). Application of active torque force simultaneously in segments with opposite actions is not wise. In the maxillary arch, applying active thirdorder bends sequentially and in only one direction at any given time is prudent.

Auxiliaries

The auxiliaries routinely used with the Tweed-Merrifield edgewise force system are elastics and directionally oriented headgear. Primarily, the high-pull J hook headgear and the straight-pull J hook headgear furnish the extraoral force in a direction manner. Patient compliance is imperative.

Variations of the Appliance

Many variations of the edgewise appliance have been introduced in the past 20 years. Most notable of the variations is the straight wire appliance introduced in 1972 by Larry Andrews. The straight wire appliance incorporates first-, second-, and third-order bends into the bracket. The theory behind this approach is that these bends will not have to be placed in the arch wire. Another variation is a change in slot size from 0.022 to 0.018 inch and even to 0.016 inch. Various orthodontic suppliers market numerous variations of the straight wire appliance with different tip and torque to suit the individual operator’s desires. Other modifications have been extensively described by Burstone, Lindquist, and Roth (see Chapters 3, 4, 14, and 15).

TREATMENT WITH THE TWEED-MERRIFIELD EDGWISE APPLIANCE

Any treatment protocol must complement a diagnostic philosophy. Using Tweed’s treatment concepts as a foundation, Merrifield developed force systems that simplify the use of the edgewise appliance. For example, Tweed used twelve sets of arch wires during the treatment of each patient. Today, with the modern edgewise appliance, only four to five sets of arch wires are used. Merrifield’s sequential directional force technology is simple, straightforward, and fundamentally sound. From the era of Tweed and into the era of Merrifield, the key to quality with the edgewise appliance continued to be directionally controlled precision arch wire manipulation. Essentially five concepts compose the treatment philosophy: (1) sequential appliance placement, (2) sequential and/or individual tooth movement, (3) sequential mandibular anchorage preparation, (4) directional forces including control of the vertical dimension to enhance mandibular response, and (5) proper timing of treatment.

Sequential Appliance Placement

The application of the appliance to the patient is important. In a first premolar extraction patient, the second molars and the second premolars are banded. Initially, the first molars are left unbanded. The central incisors, lateral incisors, and canines are bonded. Anterior teeth that are malaligned are not ligated to the arch wire or are ligated passively. This method of sequential appliance placement is less traumatic to the patient and is easier and less time consuming for the orthodontist. The method allows much greater efficiency in the action of the arch wire during the first months of treatment because it gives the posterior segment of the arch wire much longer interbracket length. This length creates a power storage that accomplishes second molar movement more rapidly. Sequential appliance placement also gives the orthodontist the opportunity to insert a wire of larger dimension that is less subject to occlusal or bracket engagement distortion.

After the bonded and bracketsed teeth respond to the forces of the arch wire and auxiliaries, the first molars are banded. The maxillary first molars are banded after one appointment. The mandibular first molars are banded after the second appointment.

Sequential Tooth Movement

Tooth movement is sequential. Tooth movement is not the en masse movement that was introduced by Tweed. Teeth are moved rapidly and with precision because they are moved individually or in small units.

Sequential Mandibular Anchorage Preparation

Tweed attempted, with varying degrees of success, to prepare mandibular anchorage with Class III elastics. All the compensation bends were placed in the arch wire at one time. The normal sequelae of this force system were labially flared and intruded mandibular incisors. Sequential mandibular anchorage preparation, developed by Merrifield, is the system that allows mandibular anchorage to be prepared quickly and easily by tipping only two teeth at a time to their anchorage prepared position. This system uses high-pull headgear rather than Class III elastics for support.
Unlike the en masse anchorage of the Tweed era, movement is controlled, sequential, and precise.

Movement is accomplished by using 10 teeth as "anchorage units" to tip two teeth, and often is referred to as the Merrifield "10-2" system. In the initial step of treatment, denture preparation, the second molar is tipped to its desired anchorage prepared position. After space is closed, a compensating bend is placed mesial to the second molar to maintain its tip, and the mandibular first molar is tipped to an anchorage prepared position. After the first molar is tipped, a compensation bend is placed mesial to the molar to maintain its tip, and the second premolar is tipped distally to its anchorage prepared position.

**Directional Force**

The hallmark of modern Tweed-Merrifield edgewise treatment is the use of directional force systems to move the teeth. **Directional forces can be defined as controlled forces that place the teeth in the most harmonious relationship with their environment.**

To use a force system that controls the mandibular posterior teeth and the maxillary anterior teeth is crucial. The resultant vector of all forces should be upward and forward to enhance the opportunity for a favorable skeletal change, particularly during dentoalveolar protrusion Class II malocclusion correction (Figure 16-14). An upward and forward force system requires that the mandibular incisor be upright over basal bone so that the maxillary incisor can be moved distally and superiorly (Figure 16-15). For the upward and forward force system to be a reality, vertical control is crucial. To control the vertical dimension, the clinician must control the mandibular plane, palatal plane, and occlusal plane. If point B drops down and back, the face becomes lengthened, the mandibular incisor is tipped forward off basal bone, and the maxillary incisor drops down and back instead of being moved up and back (Figure 16-16). The unfortunate result of this procedure is a patient with a lengthened face, a gummy smile, incompetent lips, and a more recessive chin.

**Timing of Treatment**

The timing of treatment is an integral part of the philosophy. Treatment should be initiated at the time when treatment objectives can be accomplished most readily.

**Figure 16-15**

Upright mandibular incisor and maxillary incisor moved up and back.

**Figure 16-14**

Upward and forward force system.

**Figure 16-16**

Downward and backward force system.
This may mean interceptive treatment in the mixed dentition, selected extractions in the mixed dentition, or waiting for second permanent molar eruption before initiating active treatment. Diagnostic discretion is the determinant.

**STEPS OF TREATMENT**

Tweed-Merrifield edgewise directional force treatment can be organized into four distinct steps: denture preparation, denture correction, denture completion, and denture recovery. During each step of treatment, certain objectives must be attained.

**Denture Preparation**

Denture preparation prepares the malocclusion for correction. Objectives include the following:

1. Leveling
2. Individual tooth movement and rotation correction
3. Retraction of maxillary and mandibular canines
4. Preparation of the terminal molars for stress resistance

The denture preparation step of treatment takes about 6 months. One mandibular arch wire and one maxillary arch wire are used to complete this step.

The teeth of the original malocclusion are sequentially banded and bonded (Figure 16-17). After the placement of the appliance, a 0.018- x 0.025-inch resilient mandibular arch wire and a 0.017- x 0.022-inch resilient maxillary arch wire are inserted. The loop stops are flush with the second molar tubes in each arch. The mandibular second molar receives an effective distal tip of 15 degrees from this initial arch wire. In the maxillary arch, enough tip is in the wire distal to the loop to have an effective distal tip of 5 degrees on the second molar. The objective in each arch is to maintain the maxillary molar in its distally tipped position and begin tipping the mandibular second molar to an anchorage prepared position.

A second premolar offset bend is placed mesial to the second premolar bracket in each arch wire. The purpose of this bend is to prevent the canines from expanding out of the alveolar trough as they are retracted with the headgear. The third-order bends in each arch wire are passive. High-pull J hook headgear is used to retract maxillary and mandibular canines. After each month of treatment, both arch wires are removed, and the terminal molar tip in the mandibular arch wire is increased to maintain the effective 15-degree tip as the tooth tips distally. After the first month of treatment the maxillary first molars are banded, and after the second month of treatment the mandibular first molars are banded. As the canines retract and the arches are leveled, the lateral incisors are ligated, and power chain force to aid canine retraction can be used (Figure 16-18).

One must remember that at each visit during denture preparation, the arch wires are removed; carefully coordinated; checked for proper first-, second-, and third-order bends; and religated. Canine retraction is continued with power chain and headgear force. At the end of the denture preparation stage of treatment the dentition should be level, the canines should be retraced, all rotations should be corrected, and the mandibular terminal molars should be tipped distally into an anchorage prepared position (Figure 16-19).
Denture Correction

The second step of treatment is called denture correction. During denture correction, the spaces are closed with maxillary and mandibular closing loop arch wires. Vertical support to the maxillary arch is achieved with J-hook headgear attached to hooks soldered to the maxillary arch wire between the maxillary central and lateral incisors. Vertical support of the mandibular anterior teeth is accomplished with anterior vertical elastics. The mandibular arch wire is a 0.019-×-0.025-inch working arch wire with 6.5-mm vertical loops distal to the lateral incisor brackets. The 0.020-×-0.025-inch maxillary arch wire has 7-mm vertical loops distal to the lateral incisor brackets. In both arches the loop stops are immediately distal to the brackets of the first molars (Figure 16-20). The loop stop in the mandibular arch wire incorporates a compensation to maintain the 15-degree terminal molar tip. After each activation the arch wire is removed and the compensating height of the distal leg of the loop stop in the mandibular arch wire is reduced so that the arch wire remains passive to the previously tipped second molar. The maxillary arch wire is coordinated with the mandibular arch wire and activated each month until all maxillary space is closed. At the end of space closure (Figure 16-21), the curve of occlusion in the maxillary arch should have been maintained, and the mandibular arch should be completely level with a 15-degree distal tip in the second molar. The dentition is now ready for mandibular anchorage preparation. This step positions teeth in the mandibular midarch and posterior areas into axial inclinations that will allow final coordination with the maxillary teeth for normal functional occlusion.

Sequential mandibular anchorage preparation
Sequential mandibular anchorage preparation is based on the concept of sequential tooth movement. The arch wire produces an active force on only 2 teeth while
remains passive to the other teeth in the arch. Therefore, the remaining teeth act as stabilizing or anchorage units as 2 teeth are tipped. The method is referred to as the “10-2” (10 teeth versus 2 teeth) anchorage system and it allows a quickly controlled response without serious adverse reaction. The anchorage preparation system is supported by high-pull headgear worn on anterior vertical spurs that are soldered distal to the mandibular central incisors.

Sequential mandibular anchorage preparation is initiated during the denture preparation step of treatment by tipping the second molar to a 15-degree distal inclination. After closing the mandibular space, the orthodontist checks the arch to make sure that it is level and that the second molars are tipped to a 15-degree distal angulation. This procedure is referred to as readout. At this time the second step of sequential mandibular anchorage preparation, first molar anchorage, is initiated. Another 0.019- × 0.025-inch arch wire with the loop stops bent flush against the second molar tubes is fabricated. First- and third-order bends are ideal. Gingival hooks for high-pull J hook headgear are soldered distal to the central incisors. To tip the first mandibular molars to an anchorage prepared position, a 10 degrees distal tip is placed 1 mm mesial to the first molar brackets. A compensating bend that maintains the 15 degrees of terminal molar tip is placed just mesial to the loop stop. The arch wire is now passive to the second molar and crosses the twin brackets of the first molar at a 10-degree bias (Figure 16-22, A). The second molars are now part of the 10 stabilizing units, and the first molars are the 2 teeth that receive the action of the directional forces and the arch wire. After 1 month the archwire is removed and a readout should show a 5-10 8-degree distal inclination of the first molars. The second molars should continue to readout at 15 degrees.

The third and final step of sequential mandibular anchorage preparation is to place a 5-degree distal tip 1 mm mesial to the second premolar brackets. A compensating bend is placed mesial to the first molars to maintain the first molars in their anchorage prepared position (Figure 16-22, B). This bend allows the arch wire in the second premolar area to be on a bias to the second premolar bracket when the arch wire is seated in the second molar tubes and into the first molar brackets. The arch wire must be passive in the brackets of the first molars and in the second molar tubes. The arch wire is ligated, and again the high-pull headgear is worn on the spurs soldered to the mandibular arch wire. Usually, wearing of headgear during sleeping hours is effective. During this step of anchorage preparation, the first and second molars and the 6 anterior teeth are part of the 10 stabilizing units, and the 2 premolars are the recipients of the 10-2 directional force system. At the end of mandibular anchorage preparation a readout will show that the second molars have a distal axial inclination of 15 degrees, the first molars have a distal axial inclination of 5 to 8 degrees, and the second premolars are at 0 degrees or have a distal axial inclination of 3 degrees.

The denture correction step of treatment now should be complete for the Class I malocclusion. The objectives of the denture correction step are (1) complete space closure in both arches, (2) sequential anchorage preparation in the mandibular arch, (3) an enhanced curve of occlusion in the maxillary arch, and (4) a Class I intercuspation of the canines and premolars. The mesiobuccal cusp of the maxillary first molar should fit into the

Figure 16-22
Mandibular anchorage preparation. A, 10-2-6. The first molar is tipped to its anchorage prepared position. B, 10-2-5. The second premolar is tipped to its anchorage prepared position.
mesiobuccal groove of the mandibular first molar. The distal cusps of these teeth should be discolored, as should those of the second molars.

Class II force system
For patients with an “end-on” or a full-step Class II dental relationship of the buccal segments, a new system of forces must be used to complete denture correction. A careful study of the cusp relationships will determine the force system required. Making a final diagnostic decision for Class II correction is necessary based on (1) the ANB relationship, (2) a maxillary posterior space analysis, and (3) patient cooperation. The following guidelines are used:

1. If the maxillary third molars are missing, or if the ANB is 5 degrees or less and the patient is cooperative, the system to be described will accomplish the best result. If the third molars are present and are approaching eruption, they should be removed to facilitate distal movement of the maxillary teeth.

2. If a cooperative patient has (a) a mild Class II dental relationship, (b) a normal vertical skeletal pattern (FMA of 28 degrees or less), (c) an ANB of 5 to 8 degrees, and (d) normally erupting maxillary third molars, the extraction of maxillary second molars is most advantageous. The force system to be described is used to distalize the maxillary arch into the second molar extraction space.

3. If (a) the ANB is greater than 10 degrees, (b) maxillary third molars are present, and/or (c) the patient's motivation is questionable, the first molars should be removed after maxillary and mandibular first premolar extraction space closure, or surgical correction should be considered. Facial balance and harmony after correction also should be considered carefully before making either decision.

The Class II force system cannot be used unless compliance requirements are strictly followed by the patient. If one attempts to use the Class II force system without cooperation, the maxillary anterior teeth will be pushed forward off basal bone. Patient cooperation therefore must be ensured before the use of the Class II force system.

Orthodontic correction of the Class II dental relationship
At the end of sequential mandibular anchorage preparation, a mandibular 0.0215 x 0.028-inch stabilizing arch wire is fabricated. Ideal first-, second-, and third-order bends are incorporated into the arch wire. The loop stop must be 0.5 mm short of the molar tubes, and the wire must be passive to all the brackets. Gingival spurs are soldered distal to the mandibular lateral incisors. The wire is seated and ligated, and the terminal molar is cinched tightly to the loop stop.

The orthodontist fabricates a 0.020 x 0.025-inch maxillary arch wire with closed helical bulbous loops bent flush against the second molar tubes. This arch wire has ideal first- and second-order bends. The molar segment has 7 degrees of progressive lingual crown. A gingival spur is attached to the arch wire immediately distal to the maxillary second premolar crown. Gingival high-pull headgear hooks are soldered distal to the central incisors. Class II “lay-on” hooks with a gingival extension for anterior vertical elastics are soldered distal to the lateral incisors. The closed helical bulbous loops are opened 1 mm on each side, and the arch wire is ligated in place. Class II elastics of 8 ounces are worn from the hooks on the mandibular second molar tubes to the Class II hooks on the maxillary arch wire. Anterior vertical elastics are worn from the spurs on the mandibular arch wire to the gingival extension hooks on the maxillary arch wire. The high-pull headgear is worn on the maxillary headgear hooks (Figure 16-23, A).

This force system is used for about 1 month to move the maxillary second molars distally sequentially. At the next appointment the mandibular arch wire is removed and checked, and the helical bulbous loops are again activated 1 mm. The activation of the maxillary arch wire is repeated until the second molars have a Class I dental relationship (Figure 16-23, B). When the Class I relationship of the second molars has been established, a closed coil spring is wound distal to the second premolar spur and compressed between the spur and the first molar bracket or insertion of the maxillary arch wire. (The coil spring length should be 1.5 times the space between the second premolar and the first molar brackets.) An elastic chain is stretched from the second molar to the distal bracket of the first molar. The spring and the elastic create a distal force on the maxillary first molar. Additionally, the Class II elastic is worn continuously from the mandibular second molar hook to the Class II hook on the maxillary arch wire, and an anterior vertical elastic is worn 12 hours each day (Figure 16-24). The high-pull headgear is worn on the spurs soldered to the maxillary arch wire 14 hours per day. This is an efficient force system for first molar distalization (Figure 16-25).

After the first molars are moved distally into an overcorrected Class I dental relationship, the spur that was attached distal to the second premolar bracket is removed. The coil spring is moved mesially so that it is compressed between the lay-on hook and the canine bracket. Subsequently, the maxillary second premolars and the maxillary canines are moved distally with elastic chain and headgear force (Figure 16-26). Four months of treatment with monthly reactivation should position the posterior teeth in an overcorrected Class I relationship. This system will not strain the mandibular arch if the anterior vertical elastics are worn and sufficient space is available in the maxillary posterior denture area.
Figure 16-23
Class II force system. Denture correction: maxillary second molar distalization. **A.** Step 1. A helical bulbous loop is placed against the maxillary second molar. **B.** Step 2. The helical bulbous loop pushes the maxillary molar distally.

Figure 16-24
Class II force system. Denture correction: a coil spring is trapped mesial to the first molar.

Figure 16-25
Class II force system. Denture correction: maxillary first molar distalization.

After overcorrection of the Class II dental relationship of the posterior teeth, the orthodontist fabricates a 0.020×0.025-inch maxillary arch wire with 7-mm closing loops distal to the lateral incisors. This arch wire has ideal first, second, and third-order bends. Gingival headgear hooks are soldered distal to the central incisors (Figure 16-27). The closing loops are opened 1 mm per visit by cinching the loop stops to the molar tube. The Class II force should be milder: 4 to 6 oz instead of 6 to 8 oz. The anterior vertical elastic and the maxillary
high-pull headgear are used along with these light Class II elastics. After all the maxillary space is closed, the step of denture correction has been completed, and the dentition is ready for the next step of treatment—denture completion.

**Figure 16-26**
Class II force system. Denture correction: maxillary second premolar and maxillary canine distalization. After molar distalization the premolars and canines are distalized.

**Figure 16-27**
Class II force system. Denture correction: maxillary anterior space closure. A 0.020- × 0.025-inch maxillary closing loop arch wire is used to close the maxillary anterior space.

**Figure 16-28**
Denture completion. Maxillary and mandibular stabilizing wires, along with the proper elastics and headgear force, are used to complete the orthodontic treatment.

**Denture Completion**

The third step of treatment is identified as denture completion. Ideal first-, second-, and third-order bends are placed in the finishing mandibular and maxillary 0.0215- × 0.028-inch resilient arch wires. The mandibular arch wire duplicates the previously used mandibular stabilizing arch wire. The maxillary arch wire has artistic bends and hooks for the high-pull headgear, anterior vertical elastics, and Class II elastics. Supplemental hooks for vertical elastics are soldered as needed (Figure 16-26).

The forces used during denture completion are based on a careful study of the arrangement of each tooth in each arch. The orthodontist also studies the relationship of one arch to the other and the relationship of the arches to their entire environment. The orthodontist makes necessary second- and third-order adjustments in each arch wire as needed. A progress cephalogram and tracing can be evaluated to determine the final mandibular incisor position and any minor control of the palatal, occlusal, and mandibular planes that may be needed. Study of the tracing also may reveal to the clinician the requirement for lingual root torque in the maxillary incisors. Visual clinical observations permit evaluation of the lip line, the maxillary incisor relationship, and the amount of cusp seating and artistic positioning of the incisors that is necessary.

Denture completion can be considered as muntreatment of the malocclusion. During this treatment step, the orthodontist uses the forces that are necessary until the original malocclusion is overcorrected. At the end of
the denture completion stage of treatment, the following characteristics should be observed readily:
1. The incisors must be aligned.
2. The occlusion must be overtreated to a Class I relationship.
3. The anterior teeth must have minimal incisal guidance.
4. The maxillary canines and second premolars must be locked tightly into a Class I dental relationship.
5. The mesiobuccal cusp of the maxillary first molar must occlude in the mesiobuccal groove of the mandibular first molar.
6. The distal cusps of the first molar and the second molars should be slightly out of occlusion.
7. All spaces must be closed tightly from the second premolars forward.

**Denture Recovery**

The ideal occlusion will occur after all treatment mechanics are discontinued and uninhibited function and other environmental influences active in the post-treatment period stabilize and finalize the position of the total dentition. When all appliances are removed and the retainers are placed, a most crucial “recovery” phase occurs. During this recovery period, the forces involved are those of the surrounding environment, primarily the muscles and the periodontium. If mechanical retentive procedures barely achieve normal relationships of the teeth, relapse is inevitable. Any change is likely to be away from ideal occlusion toward malocclusion. Recovery, based on a concept of overcorrection, is predicated on clinical experience and research. Certain tooth and denture changes effected during treatment will tend to revert toward their original position.

Orthodontists not familiar with the concept of overtreatment have expressed some concern about the Tweed-Merrifield posterior disclusion that is achieved at the completion of treatment. This treatment occlusion, sometimes referred to as *Tweed occlusion* but properly identified as *transitional occlusion* (Figure 16-29), is characterized by disclusion of the second molars. The mesiolingual cusp of the maxillary first molar is seated into the central fossa of the mandibular first molar with the mesial inclined plane of the mesial cusp of the maxillary first molar contacting the distal inclined plane of the mesial cusp of the mandibular first molar. This arrangement allows the muscles of mastication to effect the greatest force on the “primary chewing table” in the midarch area. The slightly inclined distally inclined maxillary and mandibular second molars now can reerupt to a healthy functional occlusion without trauma or premature contact.

Figure 16-29

Transitional occlusion. The occlusion must be overtreated to a Class I relationship. The anterior teeth should be edge to edge. The canines, second premolars, and first molars must have a solid Class I dental relationship. The second molars should be tipped out of occlusion.

Figure 16-30

Final occlusion is characterized by the teeth settling into their most efficient, healthy, and stable positions.
The muscles of swallowing, expression, and mastication are involved actively in determining the final stable, esthetic relationship of the teeth, referred to as functional occlusion. This concept of a transitional occlusion followed by a period of recovery is based on the belief that each individual's own oral environment will determine the ultimate position of the dentition and that overtreatment allows the patient the greatest opportunity for maximal stability and functional efficiency.

CASE REPORT 1 MALOCCLUSION CORRECTION WITH THE EDGewise APPLIANCE

The corrections of three malocclusions are illustrated. These patients were treated with Tweed-Merrifield edgewise appliance by Herbert Klontz, the Tweed Study Course director. The intent in showing these records of Klontz's patients is to illustrate that all treatment objectives can be attained routinely in the treatment of different types of malocclusions if the force system that has been presented is used.

The diagnosis of the first malocclusion will be described in detail to illustrate the use of craniofacial analysis and the total dentition space analysis when making the differential diagnosis and formulating a treatment plan. This malocclusion was a severe Angle's Class II with facial unbalance. The force system used to correct the malocclusion was the Class II force system previously described in this chapter.

PATIENT 1: MK

This 13-year-old girl shows a malocclusion with facial, dental, and craniofacial disharmony.

Diagnosis

Profile and full-face photographs (Figure 16-31) illustrate the protrusion and the facial imbalance. The patient has excessive gingival display on smiling. The casts (Figure 16-32) exhibit the Angle's Class II occlusion with a deep impinging overbite and flared and intrusive maxillary and mandibular incisors. The pretreatment tracing of the cephalogram (Figure 16-33) shows an ANB of 10 degrees and an AO-BO of 7 mm, indications of the severity of the Class II malocclusion. The FMA of 50 degrees and Z angle of 53 degrees indicate reflections of the intrusive face. The IMPA of 110 degrees illustrates mandibular incisors that are forward of their bony support. The differential diagnostic analysis system was used to give some objectivity to the patient's diagnosis. The craniofacial analysis shows a cranial facial difficulty total of 109 degrees (Figure 16-34). The difficulty is in two areas, the ANB and the Z angle. All other values are within normal range. The total space analysis confirms the severity of the protrusion with a cephalometric discrepancy of 13.6 mm, a curve of Spee correction of 2 mm, and a Class II correction of 8 mm. Using the difficulty values, total antegon

Figure 16-31

MK: Pretreatment facial photographs.
Figure 16-32
MK: Pretreatment casts.

Figure 16-33
MK: Pretreatment cephalometric tracing.

discrepancy was 15.1 mm, and the total midarch and occlusal disharmony discrepancy was 18 mm. The posterior discrepancy was 10 mm with a difficulty of only 5 because posterior discrepancies normally can be resolved with third molar extractions. The total space analysis difficulty was 38.1 mm. This space analysis difficulty includes the space analysis difficulty and the occlusal disharmony difficulty. The 38.1 reflects the severe protrusion and Class II occlusion problem. The craniofacial difficulty of 109 is added to the base analysis difficulty of 38.1 to give a total difficulty of 147.1. This difficulty puts the patient in the severe category and makes it evident to the clinician that the malocclusion correction is going to require not just force system application and good patient cooperation.

Treatment
Because of the severe protrusion and the immediate need to upright the mandibular incisors, the maxillary and mandibular first premolars were extracted. The patient was banded and bonded according to the protocol that has been described. The force system that has been described was used. The patient's malocclusion was corrected after 26 months of active appliance therapy. The patient's posttreatment facial photographs (Figure 16-35), when compared with the pretreatment photographs, exhibit a significant and positive change in the facial balance. The protrusion no
Figure 16-35
MK: Pretreatment (A) and posttreatment (B) facial photographs.

Figure 16-36
MK: Pretreatment (A) and posttreatment (B) casts.

longer exists and the patient has a pleasing profile. The pretreatment/posttreatment casts (Figure 16-36) exhibit control of the dentition, the creation of an ideal Angle's Class I dental relationship and the distal tipping of the second mandibular molars should be noted. These teeth have been tipped out of occlusion because of anchorage preparation that enhanced vertical control during Class II correction. Note that arch form has been maintained. After 9 months, another set of casts was made (Figure 16-37) that shows the
Figure 16-37
MK: Recovery casts.

Figure 16-38
MK: Pretreatment (A) and posttreatment (B) cephalometric tracings.

The "springing" of the transitional occlusion. (The treatment occlusion is transitional and is preplanned. If occlusion is aligned properly, the teeth settle within 6 to 18 months.) The pretreatment/posttreatment cephalometric tracings (Figure 16-38) illustrate changes in many of the values. The FMA increased from 25 to 66 degrees. Mandibular incisors were uprighted from 93 to 85 degrees, and ANB was reduced from 10 to 3 degrees. The Z angle increased from 58 to 63 degrees, a clear indication that the goals for facial
balance and harmony were met. Superimposition tracings (Figure 16-39) illustrate the control of the maxillary and mandibular molars, uprighting of the mandibular incisors and the upward and backward movement of the maxillary incisors. The direction of mandibular response was downward and forward. This downward and forward mandibular response contributed greatly to the improved facial balance and harmony. The smiling photographs of the patient (Figure 16-40) confirm the intrusion of the incisors and the considerable decrease in gingival display.

**PATIENT 2: AC**

**Diagnosis**

Profile and full-face photographs (Figure 16-41) indicate a mild protrusion of the lips. The pretreatment casts (Figure 16-42) exhibit a deep impinging overbite, an Angle's Class II dental relationship on the patient's right side, a deep curve of Spee in the mandibular arch, and a reverse curve of Spee in the maxillary arch. The cephalometric tracing (Figure 16-43) illustrates a reasonably good skeletal pattern. The ANB of

![Figure 16-39](image)

**Figure 16-39**

MK: Pretreatment (A) and posttreatment (B) superimpositions.

![Figure 16-40](image)

**Figure 16-40**

MK: Pretreatment (A) and posttreatment (B) smile. Note diminished gingival display.
Figure 16-42
AC: Pretreatment casts.

Figure 16-43
AC: Pretreatment cephalometric tracing.

Treatment

To achieve the correct Class II molar relationship in this type of malocclusion, the force system used was designed to correct the molar relationship.
He altered the denture preparation and correction steps of the protocol.

**Denture Preparation.** Denture preparation for the maxillary arch includes leveling, rotation control, bracket engagement, maxillary canine retraction, and molar positioning. In the mandibular arch, denture preparation includes all of the foregoing along with the upright mesial movement of the mandibular first molars.

The appliance is applied sequentially. Initially, the maxillary incisors, canines, second premolars, and second molars are bracketed and banded. Mandibular incisors and canines are bracketed, and the first premolars are banded. The mandibular first molars are banded with a buccal tube attachment on the band.

The initial arch wires are fabricated from resilient edgewise wire: 0.017 x 0.022 inch for the maxillary arch and 0.018 x 0.025 inch for the mandibular arch. The omega loop in the mandibular arch is enlarged significantly so that its ligature to the first molar uprights the tooth by moving the root mesially. The omega loop is 4 mm in front of the buccal tube. Ideal first, second, and third-order bends are placed, and the arch wires are ligated (Figure 16-44). If necessary, adjustments are made for canine bracket engagement. A high-pull headgear is adjusted to hook directly over the maxillary arch wire against each canine. The headgear should be checked and adjusted at each appointment for proper fit, comfort, and compliance.

At the second appointment, the arch wires are removed and adjusted. Maxillary first molar offsets are placed in the maxillary arch wire, and the maxillary first molars are bonded with regular twin brackets.

The mandibular first molars are again clinched tightly to the enlarged omega loop. The arch wires are adjusted and retied. Headgear wear to the maxillary canines is continued for 12 to 14 hours per day.

After the mandibular first molars have been uprighted and their roots have been moved mesially (usually three to four adjustments), the mandibular arch wire is replaced with a 0.019 x 0.025-inch closing loop arch wire. The loop is placed just distal to the mandibular first premolar bracket, and a shoehorn loop tie-back is bent into the arch wire just distal to the closing loop (Figure 16-45). After two or three activations of the loop the mandibular first molars will have been moved mesially to close most of the extraction space. Nighttime wear of the high-pull headgear is continued to the maxillary canines. After the use of one arch wire in the maxillary arch and two arch wires in the mandibular arch, the denture preparation treatment objectives have been met. In the maxillary arch, complete canine retraction has occurred, as has maintenance of or a slight increase in the terminal molar inclination and maintenance of the gentle curve of Spee. Objectives accomplished in the mandibular arch include second premolar extraction space closure by mesial first molar movement, tightened occlusal plane, and maintenance of the first molar inclination (Figure 16-46).

**Denture Correction.** Denture correction includes maxillary anterior protrusion reduction, space closure, posterior tooth positioning, and overbite-overjet correction. Denture correction in the mandibular arch includes incisor positioning, mandibular anchored preparation, and root paralleling for stabilization.
Figure 16-46
AC: Denture preparation—space closure complete. The shoehorn loop should close the mandibular second premolar extraction space completely.

To prepare terminal molar anchorage in the mandibular arch, the first molar bands with the buccal tube attachments are removed and the second molars are rebanded. The first molars are not rebanded at this time. (They are rebanded after the second molars begin to become upright.) A 0.019- x 0.025-inch arch wire with loop stops flush against the mandibular second molar tubes is fabricated. Proper first- and third-order bends are placed. Fifteen degrees of active distal tip is placed on the mandibular second molars. A 0.020- x 0.025-inch maxillary arch wire with 7.5-mm closing loops distal to the lateral incisors is fabricated. The loop tip is immediately distal to the first molar bracket. Original headgear hooks are soldered distal to the central incisors (Figure 16-47).

The arch wires are ligated, the maxillary closing loop is activated, and the maxillary headgear is slipped to the hook between the central and lateral incisors. Vertical elastics are worn to support the mandibular anchorage preparation. As the mandibular second molar starts to become upright, the first molar can be banded. The mandibular arch wire should be adjusted by placing a first molar offset and vertical height adjustment to prevent first molar intrusion. The second molar distal tip is increased so the effective tip remains at 15 degrees.

In the maxillary arch, space closure is continued, whereas in the mandibular arch the second molar is repressed and tipped gradually to a 15-degree distal inclination. When (1) the mandibular arch has been retracted completely and (2) the mandibular second molar has a 15-degree distal inclination, mandibular anchorage preparation as previously described is accomplished. Treatment is completed as it is for any Class I malocclusion.

Treatment Results
The posttreatment facial photographs (Figure 16-48) illustrate a subtle facial change. The protrusion has been reduced, and the patient now has a more pleasing and balanced face. The posttreatment dental casts, compared with the pretreatment casts (Figure 16-49), illustrate the correction of the Class II malocclusion, intrusion of the maxillary incisors, and the mildly tipped teeth in the posterior part of both arches. Arch form has been maintained, and mandibular crowding has been eliminated. The pretreatment/posttreatment cephalogram tracing comparison (Figure 16-50) confirms maintenance of the pretreatment position of the mandibular incisors, reduction of the ANB from 7 to 3 degrees and improvement in the Z angle from 58 to 72 degrees. The superimposition (Figure 16-51) graphically illustrates the control of the maxillary and mandibular molars and the vertical dimension, maintenance of mandibular incisor position, and the distal and superior movement of the maxillary incisors. Recall facial photographs (Figure 16-52) show a pleasing facial profile and a beautiful smile. The recall casts (Figure 16-53) confirm excellent settling of the occlusion into an ideal Class I dental relationship.
Figure 16-48
AC: Pretreatment (A) and posttreatment (B) facial photographs.

Figure 16-49
AC: Pretreatment (A) and posttreatment (B) dental casts.

PATIENT 3: MB

Diagnosis
MB's records demonstrate diagnostic differentiation for a less severe malocclusion. The pretreatment profile and full-face photographs exhibit a balanced face with some maxillary lip protrusion and a mild facial asymmetry (Figure 16-54). The casts (Figure 16-55) reveal a Class II buccal segment relationship with flared maxillary incisors caused by a digit and tongue habit. The tracing of the pretreatment cephalogram (Figure 16-56) confirms a fairly normal skeletal pattern with an FMA of 24 degrees and an IMPA of 90 degrees. The ANB is 4 degrees, and the Z angle is already 82 degrees. The total difficulty value from the differential diagnosis and clinical analysis protocol was 45.
Figure 16-50
AC: Pretreatment (A) and posttreatment (B) cephalometric tracings.

Figure 16-51
AC: Cephalometric tracing superimpositions.

This value reflects a mild cranial and dental problem. The fact that there was no anterior discrepancy, a mild curve of Spee of 2 mm, and an occlusal disharmony of 4 mm puts this patient into the non-premolar extraction category.

Treatment
Treatment of a patient whose diagnosis dictates non-premolar extraction, Class II or I, with Merrifield edgewise sequential directional forces is similar to the treatment previously discussed. One must understand, however, that Class II malocclusion correction generally requires more anchorage preparation than Class I correction because Class II elastics generally are used. The overall objectives of proper dentition positioning and excellent facial esthetics are the same, whether the patient is treated by extraction or nonextraction of premolars. In most non-premolar extraction patients, treatment requires more attention to anchorage conservation than is necessary with premolar extraction treatment. The posterior part of the dentition must be analyzed carefully because the mandibular arch must have space for anchorage preparation. In most patients, adequate space for mandibular anchorage preparation and proper tooth positioning requires the extraction of the mandibular third molars before treatment.
Likewise, space must be present in the posterior part of the maxillary arch for Class II correction. Diagnoses and treatment planning is crucial in this area because frequently the maxillary third molars should be extracted before the Class II correction step of treatment.
The treatment of the non-premolar extraction patient is divided into the same four steps of treatment that have been outlined previously: denture preparation, denture correction, denture completion, and denture recovery.

**Denture Preparation.** The dentition is banded and bonded sequentially. A 0.018- × 0.025-inch mandibular arch wire with arch curvature and with 5-mm omega loops bent flush against the second molar tubes is used. About 5 degrees of effective distal tip should be against the second molars when the wire is ligated. The maxillary arch wire is a 0.017- × 0.022-inch with 7-mm helical loops bent flush against the second molar tubes. The effective distal tip on the molars is about 5 degrees. Hooks are soldered to each wire distal to the lateral incisors for the attachment of J hook headgear (Figure 16-57, A). A useful addition to the non-premolar extraction Class II malocclusion correction is the simultaneous use of high-pull headgear on the maxillary and mandibular arch wires during denture preparation.

The purpose of both headgears is not to correct the molar relationship but to prevent downward and forward migration of the anterior teeth during sequential
Figure 16-55
MB: Pretreatment dental casts.

As described in the maxillary arch and forward tipping of the anterior teeth during sequential banding and posterior anchorage preparation in the mandibular arch. After each month of treatment, the arch wires are removed, the bulbous loops are activated 1 mm, and additional teeth are banded or bonded (Figure 16-57, B). As the arch wires are adjusted, the effective distal tip of the mandibular arch wire on the second molar is increased to a full 15 degrees as the second molar tips distally.

During denture preparation, a new 0.019" x 0.025" mandibular working arch wire is constructed. Anchorage preparation is initiated after all teeth are banded and the second molars have been tipped to a 15-degree distal inclination. This arch wire has ideal first and third-order bends, and the loop stops are flush with the second molar tubes. Using this 0.019" x 0.025" mandibular arch wire, anchorage is prepared by placing a compensation bend mesial to the loop stop to ensure that the wire is passive in the.

Figure 16-54
MB: Pretreatment facial photographs.

Figure 16-56
MB: Pretreatment cephalogram tracing.
Figure 16-57
MB: Denture preparation—non-premolar extraction. A, Initial arch wires are designed to begin mandibular terminal molar anchorage preparation and maxillary second molar distalization. B, After 1 month the loops are activated more and additional teeth are banded or bonded.

buccal tube and then by tipping the first molar 10 degrees. After the first molar is tipped distally, a compensation bend is placed mesial to the first molar, and the second premolar is tipped distally 5 degrees. These steps have been outlined previously.

Denture Correction. A 0.0215- x 0.028-inch stabilizing arch wire is used in the mandibular arch. The arch wire has ideal first-order and third-order bends. The loop stops are bent 0.5 mm anterior to the molar tubes. Gingival 0.025-inch spurs for up and down elastics are soldered distal to the lateral incisors.

A 0.020- x 0.025-inch working arch wire is used in the maxillary arch. The first-order and third-order bends are ideal. The posterior area has 7 degrees of progressive lingual crown torque. Seven-millimeter helical loops are placed in contact with the second molar tubes. Gingival high-pull headgear hooks are soldered between the central and lateral incisors, and Class II hooks are soldered between the lateral incisors and canines.

The Class II mechanics that are used have been described previously in the technique section of this chapter. To move the second molars distally, the bulboous loops are opened 1 mm per side each month. Coil springs are used to move the first molars distally along the wire. If the Class II correction is mild, the second premolars, first premolars, and canines will “follow” the molars. Elastic chains will close any space that is opened. In a more difficult Class II problem, the coil is moved mesial to the canine. The canine and premolars are moved distally with the coil spring as previously described. As the maxillary buccal segments move distally, it may be necessary to widen the arch

wire slightly to prevent buccal crossbite. The maxillary arch wire is checked, and the terminal molar tubes are cut and reattached at each monthly interval. After maxillary posterior tooth distalization in the more severe Class II problem, a 0.020- x 0.025-inch closing loop arch wire is fabricated. The closing loops are 1 mm distal to the lateral incisor brackets. The closing loops are activated 1 mm per month by ligating the omega loop to the buccal tube. The auxiliaries worn to complement this force system are a high-pull headgear to the hooks that are soldered gingival to the wire between the maxillary central and lateral incisors. Eight-ounce Class II elastics are worn 24 hours per day.

Figure 16-58
MB: Cephalogram with tongue crib.
Anterior vertical elastics also are worn when the headgear is in use.

**Denture Completion.** The previous 0.0215- x 0.028-inch mandibular stabilizing wire is removed and checked for ideal first-, second-, and third-order bends. A 0.0215- x 0.028-inch maxillary arch wire with ideal first-, second-, and third-order bends is fabricated and coordinated carefully with the mandibular arch wire. The omega loops in both arch wires are placed in 0.5 mm mesial to the molar tubes. Cusp seating spurs and hooks for the headgear and elastics are soldered. The force system can be any combination of elastics and headgear. After appliance removal, maxillary and mandibular Hawley retainers are constructed and delivered.

**Treatment Results**

During the treatment of this patient, a maxillary lingual arch with a tongue crib was placed (Figure 16-58). This addition to the appliance facilitated control of the tongue and thumb and allowed the patient's treatment to be completed successfully. The pretreatment/posttreatment facial photographs (Figure 16-59) confirm the improvement in the harmony and balance of the lower face. The casts (Figure 16-60) illustrate the correction of the Angle's Class II dental relationship.

**Figure 16-59**


**Figure 16-60**

MB: Pretreatment [A] and posttreatment [B] dental casts. Note the spaces between the maxillary first and second molars (arrows).
Case Report 1—continued

closure of the anterior open bite, and retraction of the maxillary incisors. Note the spaces between the maxillary first and second molars caused by the use of the helical bulbous loop and Class II force system. Arch form was maintained, and mandibular canines were not expanded. The pretreatment/posttreatment cephalograms (Figure 16-61) are included to illustrate molar control and distalization of the maxillary arch. Note that maxillary and mandibular third molars were extracted before treatment. The cephalogram tracings (Figure 16-62) illustrate control of the dentition and of the skeletal pattern during the tooth movement.

This control was essential for the correction of the malocclusion. The superimpositions (Figure 16-63) confirm good management of the dentition, distalization of the maxillary arch, and uprighting of the maxillary incisors. Retention for a patient like MB is important. Sometimes the tongue crib appliance is imbedded in the retainers. Unless embedding of the tongue crib is accomplished, the clinician can never be sure that the patient will not harm a beautiful orthodontic result by further tongue thrusting. The smiling photographs of the patient (Figure 16-64) illustrate the balance of the face and the beauty of the finished dentition.

Figure 16-61

Figure 16-62
Figure 16-63
MB: Cephalometric tracing superimpositions.

Figure 16-64
MB: Smiling photographs. Pretreatment (A); Posttreatment (B).
SUMMARY

The treatment of these three patients illustrates the use of the Tweed-Merrifield edgewise appliance. Proper treatment for each of these patients required correct diagnostic decisions and precise arch wire manipulation. Each required a slightly different alteration to the basic mechanical force system. In all patients the force vector must be controlled directionally to improve a poor skeletal and dental relationship or to maintain a good skeletal relationship and improve a poor dental relationship.

The standard edgewise appliance has endured the test of time. Angle was determined to use it to correct malocclusions while preserving the “full complement of teeth.” Angle collaborated with Charles H. Tweed who, after countless failures, introduced the extraction of four first premolars and anchorage preparation to produce facial balance. The appliance has continued through many more years of achievements with Lavern Merrifield, who introduced the following: (1) differential diagnosis, which led to the removal of those teeth that would best produce balance, harmony, and facial proportion within the craniofacial complex; (2) directional force technology; and (3) sequential wire manipulation treatment. The edgewise appliance has become a precise instrument for the routine correction of major malocclusions. Although the Tweed-Merrifield edgewise appliance is the direct descendant of the appliance invented in 1926 by Edward H. Angle, it is used with a totally different philosophy of treatment. A consistent effort is being directed continuously toward the further sophistication of this wonderful appliance. The edgewise appliance has stood the test of time and will be used by many more generations of orthodontists.

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