Standard Edgewise: Tweed-Merrifield Philosophy, Diagnosis, Treatment Planning, and Force Systems

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Nothing worthwhile ever departs.

HISTORICAL PERSPECTIVE

An obsession for order motivated Edward Hartley Angle (Fig. 19-1) to create, in 1888, the Angle system. This system ultimately resulted in the introduction of the edgewise multibanded appliance 5 years before Angle's death, which has been the progenitor of all modern appliances.

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 patient treatment that motivated and inspired him to develop a standard appliance.[1,2] 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 and anchorage.
4. **Delicacy:** It must be accepted by the tissues, and it must not cause inflammation and soreness.
5. **Inconspicuousness:** It must be aesthetically acceptable.

Angle designed a standard appliance composed of a specific number of basic components (Fig. 19-2). He had these
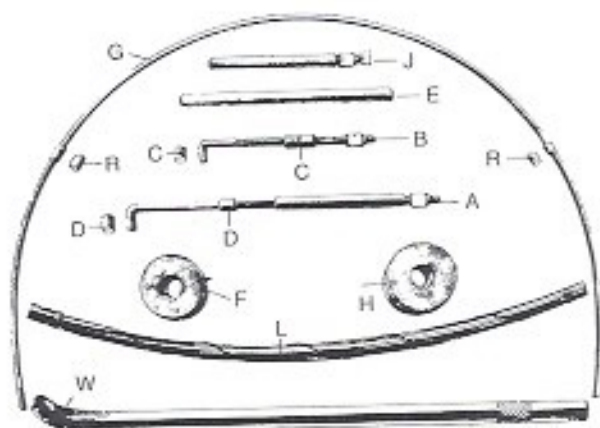
FIGURE 19-1 Edward H. Angle.

FIGURE 19-2 The basic components of Angle's standard appliance, illustrating traction screws (A, B), attachment tubes (C, D), jackscrews (E, J), lever wires (L), band material (F, H), archwire (G), wrench (W), and archwire lock (R). (From Angle EH: *Treatment of Malocclusion of the Teeth.* Philadelphia: SS White; 1907.)

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 discomfort to the patient. This universal application 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 among manufacturers, suppliers, and orthodontists; it was the Angle system.

THE EDGEWISE APPLIANCE

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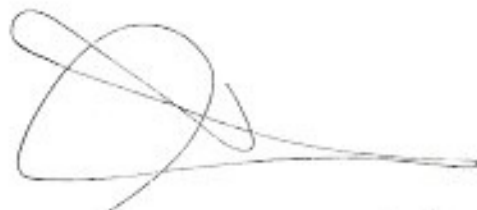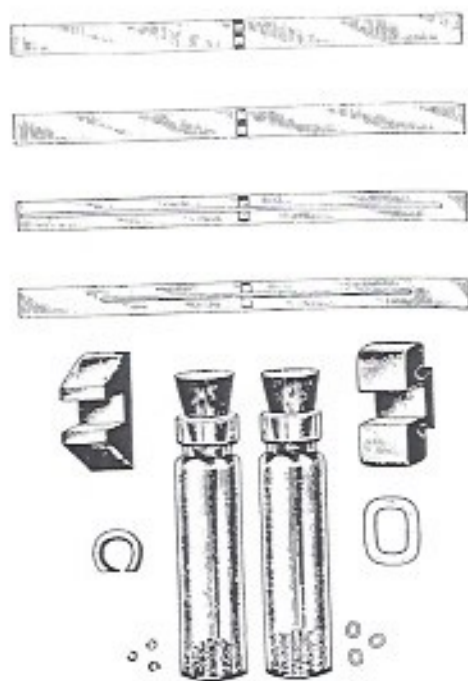

FIGURE 19-3 Original edgewise brackets.

predecessors 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 archwire was held in position first by a brass ligature and later by a delicate stainless steel 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 (Fig. 19-3). 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 (Fig. 19-4). Angle was bitterly disappointed by the reception that had been 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*. He asked Tweed to help him with the article because Tweed had just finished the Angle "course" and because he admired and respected Tweed's ability

FIGURE 19-4 Charles H. Tweed.

For 7 weeks, they worked together and in the process became close friends. During this time, Angle advised Tweed that he could never master the edgewise appliance unless he limited his practice solely to its use. And so with the completion of the article for *Dental Cosmos*, Charles Tweed returned to Arizona and established in Phoenix what was probably the first pure edgewise specialty practice in the United States.

For the next 2 years, the two men worked together closely. Tweed treatment planned and treated his patients, and Angle acted as his advisor. Angle was pleased with Tweed's treatment and was instrumental in getting Tweed on several programs. During these 2 years, in a series of more than 100 letters that are now housed in the Tweed Memorial Center Library, Angle urged his young disciple to carry out two vital requests: (1) to dedicate his life to the development of the edgewise appliance and (2) to make every effort to establish orthodontics as a specialty within the dental profession.

Tweed followed Angle's advice. First, he instigated the passing of the first orthodontic specialty law in the United States. He did this by canvassing patients, persuading dentists, influencing and arousing politicians, speaking at meetings, having petitions signed, and even taking patients before the legislature. In short, it was a one-man blitz. His untiring and relentless efforts were successful, and in 1929, the Arizona legislature passed the first law limiting the practice of orthodontics to specialists. Tweed received Certificate No. 1 in Arizona and became the first certified specialist in orthodontics in the United States.

In 1932, Tweed published his first article in the *Angle Orthodontist*. It was titled "Reports of Cases Treated with Edgewise Arch Mechanism."[3] Tweed held to Angle's firm conviction that one must never extract teeth. This conviction lasted for 4 years.

The facial aesthetics Tweed began to observe in his patients was discouraging to him, so discouraging in fact that he almost gave up orthodontic practice. He knew he had the appliance, and he knew he had the ability, but his results were aesthetically unsatisfactory and unstable. He devoted the next 4 years of his life to the study of his successes and failures. During this 4-year period, he made a most important observation: upright mandibular incisors frequently were related to both posttreatment facial balance and stability of the treated dentition. To

position mandibular incisors upright, he concluded that one must, in many instances, extract teeth and prepare anchorage. He selected his failures, extracted four first premolar teeth, and retreated the patients. He did this without charging a fee.

In 1936, Tweed delivered a paper on the extraction of teeth for orthodontic malocclusion correction to the membership of the Angle Society and subsequently published it.[4,5] "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 who were first treated with nonextraction and later 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. Robert Strang, one of Angle's students in the early years, described the event this way:[6]

> 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 lacing into 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 casts 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 shouted 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 four objectives of orthodontic treatment: aesthetics, health, function, and stability, with emphasis and concern for balance and harmony of the lower face.
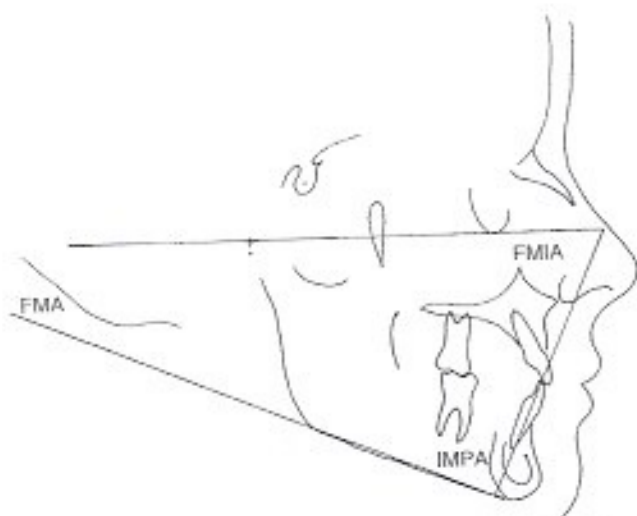
FIGURE 19-5 Tweed's diagnostic facial triangle. *FMA*, Frankfort mandibular plane angle; *FMIA*, Frankfort mandibular incisor axis angle; *IMPA*, lower incisor mandibular plane angle.

FIGURE 19-6 Levern Merrifield.

2. He developed the concept of positioning teeth over basal bone with emphasis on the mandibular incisors.[7]
3. He made the extraction of teeth for orthodontic correction acceptable and popularized the extraction of the first premolars.[8]
4. He enhanced the clinical application of cephalometrics.
5. He developed the diagnostic facial triangle[9] in order to make cephalometrics a diagnostic tool and a guide in treatment and in the evaluation of treatment results (Fig. 19-5).
6. He developed a concept of orderly treatment procedures and introduced anchorage preparation as a major step in treatment.[10]
7. He developed a fundamentally sound and consistent preorthodontic guidance program that popularized serial extraction of primary and, later, 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's skill and 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.

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 (Fig. 19-6). Tweed asked Merrifield to join him and be the codirector of his course. Merrifield took Tweed's course in 1953 and became a member of Tweed's staff in 1955. He became the course director 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 disseminated and popularized. They include the following:

Diagnostic Concepts

1. The fundamental concept of dimensions of the dentition[11]
2. Dimensions of the lower face[12]
3. Total space analysis[13]
4. Guidelines for space management decisions to achieve the following:
   a. Facilitate maximum orthodontic correction of a malocclusion.
   b. Define areas of skeletal, facial, and dental disharmony.[14]

Treatment Concepts

1. Directional force control during treatment[15]
2. Sequential tooth movement
3. Sequential mandibular anchorage preparation[16]
4. The organization of treatment into four orderly steps that have specific objectives
   Merrifield's innovations in diagnosis and treatment planning and his experience with the edgewise appliance have augmented Tweed's contributions and concepts to give modern orthodontists a more accurate, reliable, precise, efficient, and practical protocol of diagnosis, treatment planning, and treatment. Adherence to this protocol allows the clinician to do the following:
   a. Define objectives for the face, the dentition, and the skeletal pattern.
   b. Properly diagnose the malocclusion and treatment plan the malocclusion correction.
   c. Use the edgewise appliance to reach 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, intrusively, and extrusively. 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 includes four basic premises, *provided that the musculature is normal:*

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

Premise 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.

Premise 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.

Premise 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 directional force treatment with 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 enables the clinician to arrive at a differential diagnosis[17,18] 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 influenced by protrusion and crowding of the teeth. Protruded teeth cause facial imbalance. 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

FIGURE 19-7 Upper lip equals total chin. Upper lip thickness should equal total chin thickness in a balanced face.

labial surface of the maxillary incisors; thus, lip protrusion is a reflection of the degree of maxillary incisor protrusion. Maxillary incisor position is related directly, of course, to the position of the mandibular incisors.

Facial disharmonies can often be 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.[19] The Frankfort mandibular plane angle (FMA) is a skeletal angular value that is crucial in differential diagnosis. Dental compensation for a patient with a high FMA requires additional uprighting of mandibular incisors. Lower facial balance for the patient with a high FMA can be improved dramatically by using this knowledge.

Conversely, dental compensation for a patient with 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.[20,21] Poor soft tissue distribution needs to be identified during differential diagnosis so that 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 (Fig. 19-7). Total chin thickness is measured horizontally from the NB (Nasion-pt B) 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 more upright 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 clearly understand its impact on the overlying soft tissue.[22]

The profile line and its relationship to facial structures and to the Frankfort plane can be used to give the orthodontic practitioner an idea of lip procumbency. If the profile line lies outside

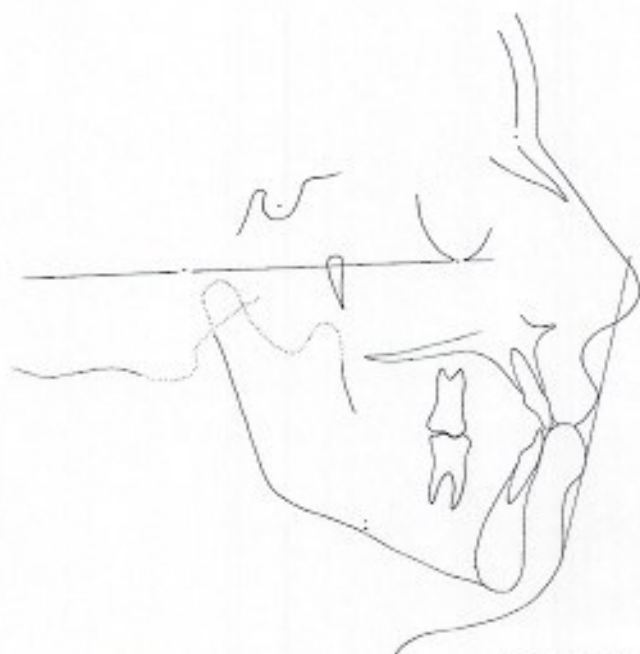FIGURE 19-8 Profile line drawn on a protrusive face.

FIGURE 19-9 Profile line drawn on a facial profile that exhibits balance and harmony.

the nose, a protrusion exists (Fig. 19-8). 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 it should lie in the anterior one third of the nose (Fig. 19-9). For centuries, the premise has been that this type of relationship of the profile line to the lips, chin, and nose reflects 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.

FIGURE 19-10 The Z angle and Frankfort mandibular incisor axis angle (FMIA). Tweed used the FMIA as an indicator of facial balance. Merrifield's Z angle quantifies balance of the lower face.

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) (Fig. 19-10).

Z Angle

The chin/lip soft tissue profile line relationship to the Frankfort horizontal plane quantifies facial balance (see Fig. 19-10). The normal range is 70 to 80 degrees.[12] 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, either anterior or posterior, can influence the Z angle.

The Z angle quantifies the combined abnormalities in the values of the FMA, FMIA, and soft tissue thickness because 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.

Frankfort Mandibular Incisor Angle

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 (see Fig. 19-10).

The records of one patient shown in Fig. 19-11 graphically illustrate the facial aesthetics "issue" in orthodontics. The pretreatment facial photographs (Fig. 19-11) confirm an acceptable face. The casts (Fig. 19-12) reflect mild crowding and a very moderate Class II occlusion. The pretreatment cephalometric tracing (Fig. 19-13) shows skeletal and dental values that are "almost" normal.

The patient was treated for 18 months without regard for facial aesthetics (Fig. 19-14). The progress cephalometric
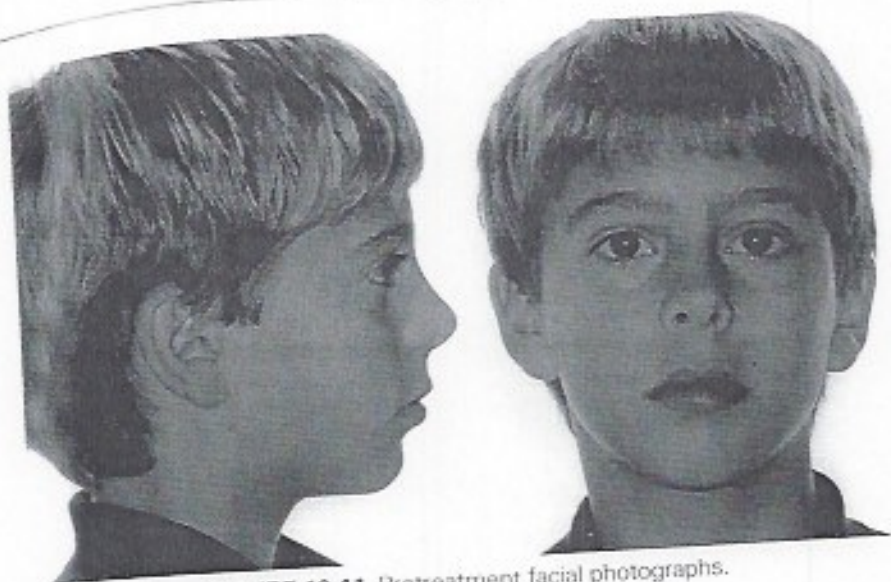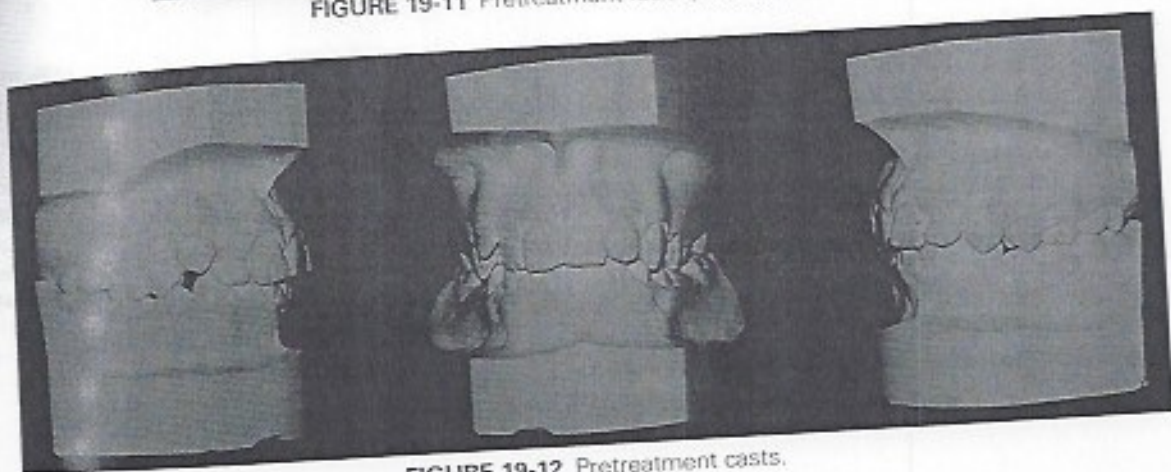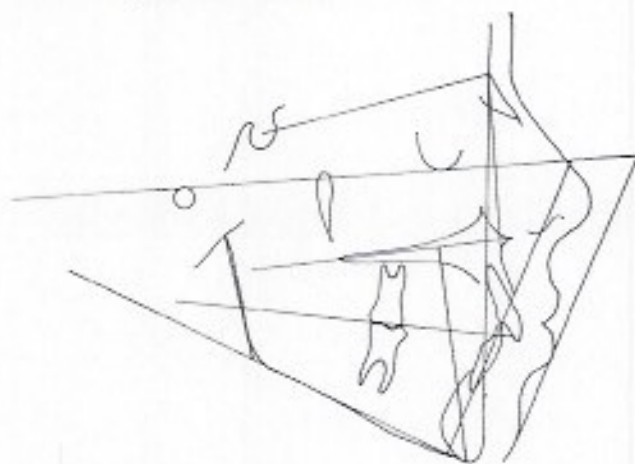
FIGURE 19-11 Pretreatment facial photographs.

FIGURE 19-12 Pretreatment casts.

FMIA	64	OCC	9	
FMA	30	Z	63	
IMPA	86	UL	14 mm	
SNA	78	TC	12 mm	
SNB	75	PFH	41 mm	
ANB	3	AFH	67 mm	
AO-BO	0 mm	Index	0.61	

FIGURE 19-13 Pretreatment cephalometric tracing. *AFH*, Anterior facial height; *ANB*, subspinale-nasion-supramentale angle; *AO-BO*, Subspinale (Pt. A) perpendicular to occlusal plane Supramentale (Pt B) perpendicular to occlusal plane; *FMA*, Frankfort mandibular plane angle; *FMIA*, Frankfort mandibular incisor axis angle; *IMPA*, incisor mandibular plane angle; *OCC*, The angle made by occlusal plane when it intersects Frankfort; *PFH*, posterior facial height; *SNB*, sella-nasion-subspinale angle; *SNB*, sella-nasion-supramentale angle; *TC*, total chin thickness; *UL*, upper lip thickness; *Z*, angle is the inferior angle the profile line makes with Frankfort horizontal plane.
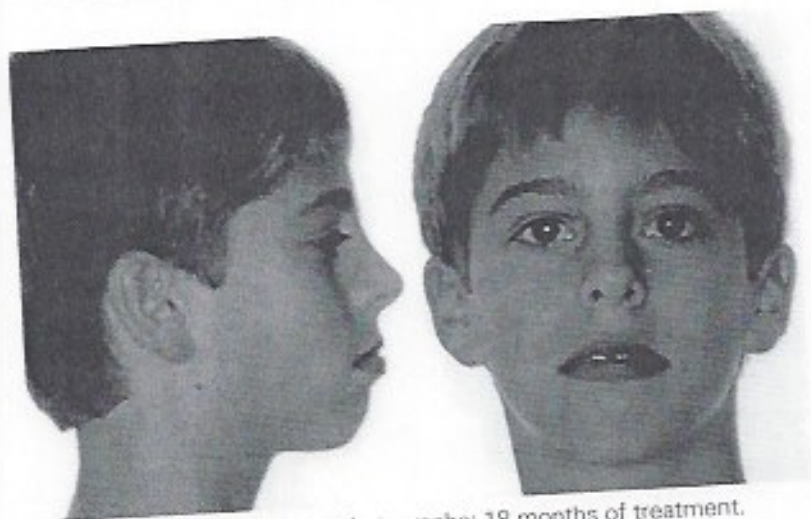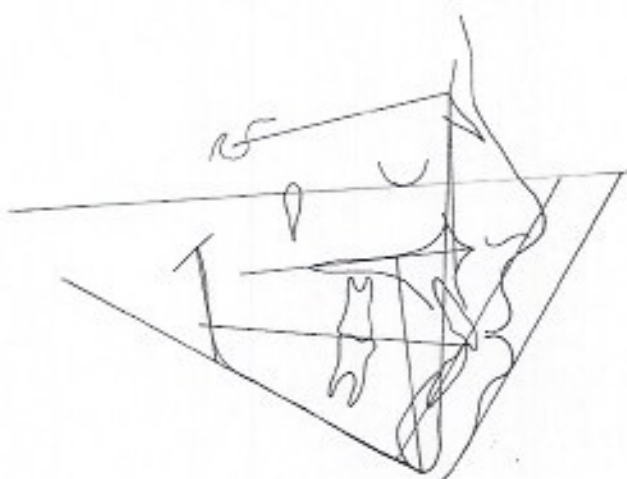
FIGURE 19-14 Facial photographs: 18 months of treatment.

FMIA	53	OCC	7
FMA	32	Z	56
IMPA	95	UL	14 mm
SNA	78	TC	10 mm
SNB	74	PFH	43 mm
ANB	4	AFH	72 mm
AO-BO	2 mm	Index	0.59

FIGURE 19-15 Progress cephalometric tracing. See Figure 19-13 for abbreviations.

tracing (Fig. 19-15) illustrates mandibular incisor flaring and loss of vertical dimension control. Compare the pretreatment photos with the "progress" photographs (Fig. 19-16). Note the respective profile lines.

The patient's treatment plan was altered. Premolars were removed. The posttreatment facial photographs (Fig. 19-17) show a balanced face. The posttreatment casts (Fig. 19-18) illustrate a well-interdigitated occlusion. The posttreatment cephalometric tracing (Fig. 19-19) confirms mandibular incisors that are now in a proper position over basal bone. The pretreatment, "progress," and posttreatment facial photographs (Fig. 19-20) illustrate the Tweed-Merrifield concept of treatment planning for maximum balance and harmony of the lower face.

Cranial Disharmony

An analytic assessment of the skeletal pattern is an integral part of any diagnosis. A careful cranial analysis must include an understanding of the following information, which can be gleaned from a cephalogram (Figs. 19-21 and 19-22).

Skeletal Analysis Values

Frankfort Mandibular Plane Angle. 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 reflects a skeletal pattern with normal growth direction. An FMA greater than the normal range indicates excessive vertical growth direction, and an FMA less than the normal range indicates deficient vertical growth.

Incisor Mandibular Plane Angle. The incisor mandibular plane angle (IMPA) defines the axial inclination of the mandibular incisors 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 mandibular incisor position that with a normal FMA will ensure optimal balance and harmony of the lower face. If the FMA is above normal, the orthodontist must dentally compensate with more uprighting of the mandibular incisors. If the FMA is below the normal range, compensation can be made by leaving the mandibular incisors in their pretreatment position or, in rare instances, by positioning them more to the labial. Labial inclination of the mandibular incisors is generally limited to their original inclination if the patient has normal muscular balance.

Sella-Nasion-Subspinale Angle (SNA). The sella-nasion-subspinale (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. The sella-nasion-supramentale (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. The normal range for the subspinale-nasion-supramentale (ANB) angle is 1 to 5 degrees. This value expresses a very "treatable" horizontal
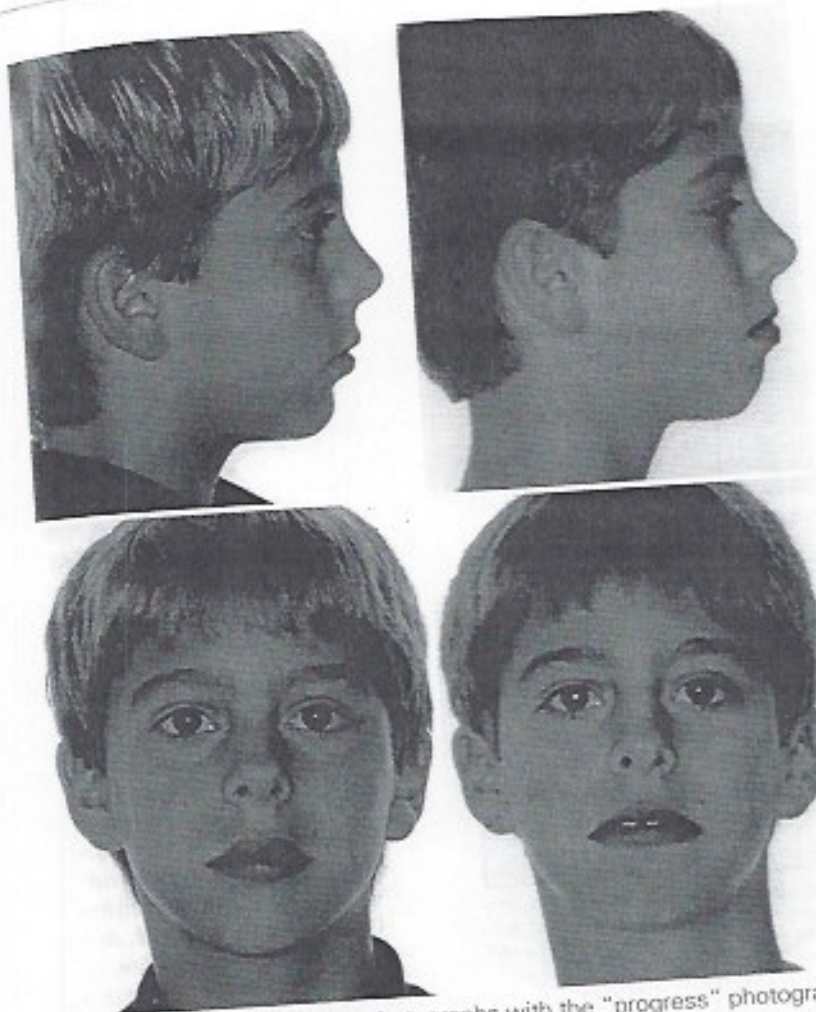
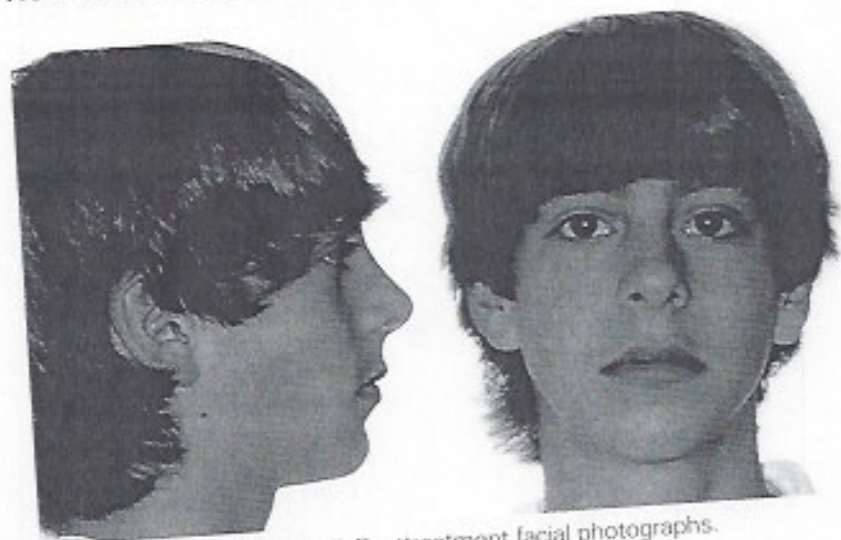FIGURE 19-16 Pretreatment photographs with the "progress" photographs.

FIGURE 19-17 Posttreatment facial photographs.

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 will usually 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 for the need of surgical assistance in Class III malocclusion correction.

Subspinale (Pt. A) perpendicular to occlusal plane; supramentale (pt. B) perpendicular to occlusal plane. Orthodontic treatment becomes more difficult when the AO-BO is outside the normal range of 0 to 4 mm. The AO-BO changes in direct proportion to the occlusal plane angle.
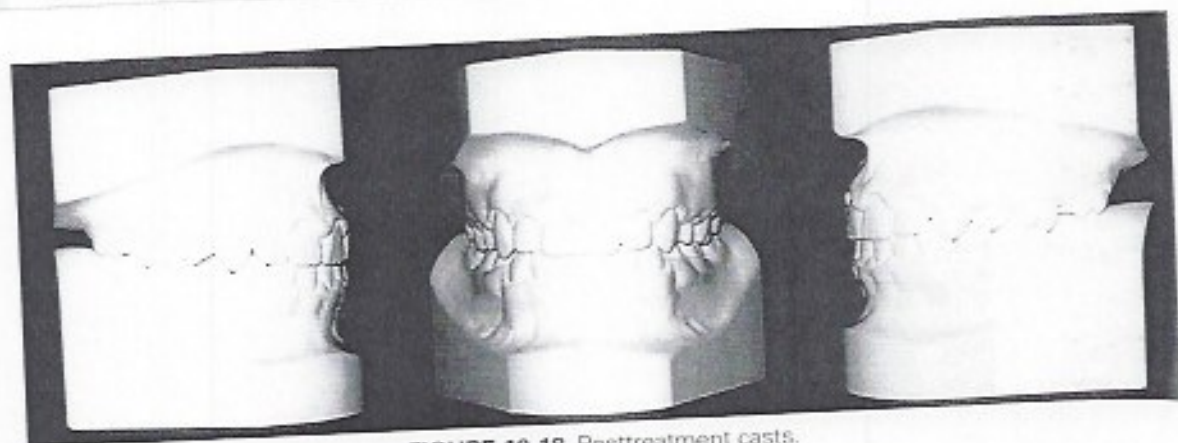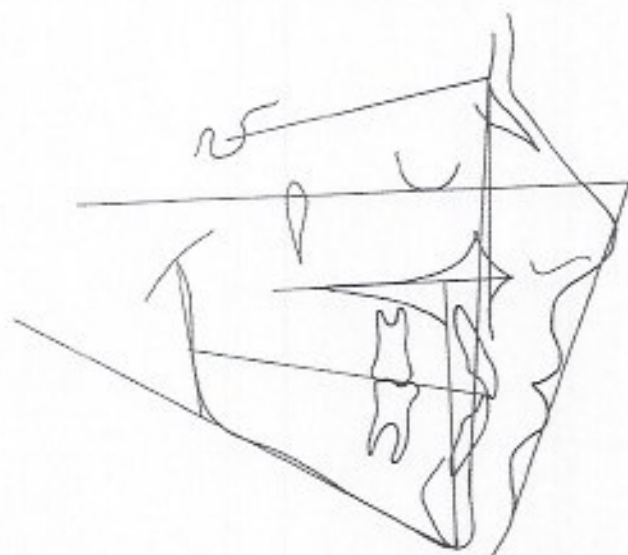
FIGURE 19-18 Posttreatment casts.

FMIA	66	OCC	9
FMA	30	Z	71
IMPA	84	UL	17 mm
SNA	78	TC	12 mm
SNB	76	PFH	47 mm
ANB	2	AFH	74 mm
AO-BO	−1 mm	Index	0.63

FIGURE 19-19 Posttreatment cephalometric tracing. See Figure 19-13 for abbreviations.

Occlusal Plane. The occlusal plane angle expresses a dentoskeletal 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 females averages about 9 degrees and for males about 11 degrees. Values greater or less than the normal range indicate more difficulty in treatment. During most orthodontic malocclusion corrections, the original value should be maintained or decreased. An increase in the occlusal plane angle during treatment indicates a loss of vertical 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. The result is a detrimental relapse of the "corrected" interdental relationship.

Posterior Facial Height. Posterior facial height (PFH) is a linear millimetric measurement of ramus height from articulare

to the mandibular plane tangent to the posterior border of the ramus. The value is related to facial form, vertically and horizontally. The relationship of PFH to anterior facial height determines the FMA and lower facial proportion. In a growing child with a Class II malocclusion, ramal growth change and its relationship to anterior facial height in proportion and in volume are crucial.

Anterior Facial Height. Anterior facial height (AFH) is a linear millimetric measurement of the vertical distance between the palatal plane and menton. The line is drawn 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 5 mm more or less than normal. During Class II malocclusion correction, limiting an increase in AFH is essential and can be accomplished by controlling maxillary and mandibular molar extrusion in conjunction with an anterior "high-pull" force on the maxilla.

Facial Height Index. André Horn[23] studied the relationship of AFH to PFH. After developing the facial height index, he found that normal PFH is 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 more difficulty in correction. An index of 0.80 is severe and indicates a "low 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. Radziminski,[24] Gebeck and Merrifield,[25,26] Issacson,[27] Pearson,[28,29] and Schudy[30] 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[26,31,32] concluded that successfully treated patients exhibited favorable mandibular changes. These changes occurred in part because AFH was controlled while PFH increased. Unsuccessful treatment results were more likely to occur in patients in whom an increase was observed in AFH but not in PFH.

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.[33,34]
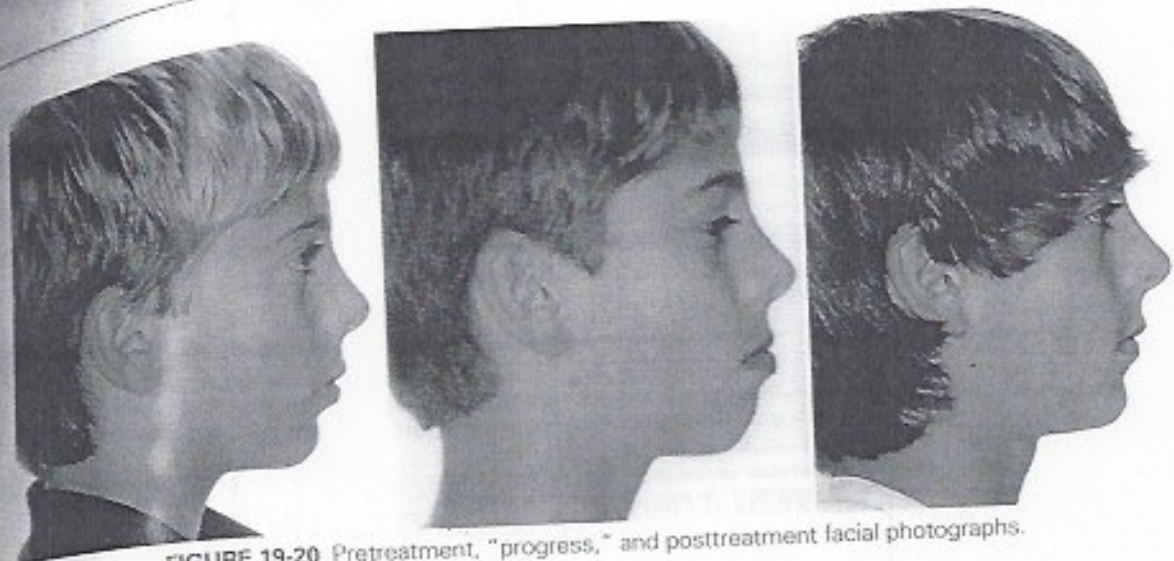
FIGURE 19-20 Pretreatment, "progress," and posttreatment facial photographs.
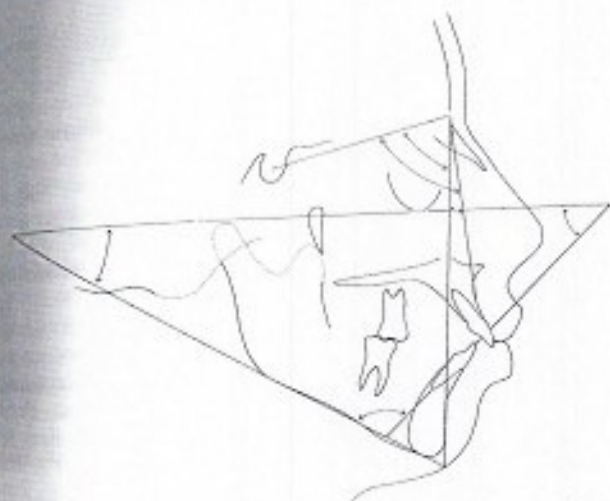

FIGURE 19-21 Cephalometric tracing with all values and planes.

FIGURE 19-22 Cephalometric tracing with all values and planes.

TABLE 19-1 The Probability Index Variables with Statistically Computed Difficulty Factors*

Cephalometric Angle	Variation
FMA	5 points
ANB	15 points
FMIA	2 points
Occlusal plane	3 points
SNB	5 points

* This was Gramling's initial attempt at a probability index.
ANB, Subspinale-nasion-supramentale angle; FMA, Frankfort mandibular plane angle; FMIA, Frankfort mandibular incisor axis angle; SNB, sella-nasion-supramentale angle.

From the background of evidence gathered from these studies, Gramling formulated a probability index[35] for three specific purposes:

1. To augment diagnostic procedures
2. To guide treatment procedures
3. To predict possible treatment success or failure

Gramling statistically established a difficulty factor and assigned a specific number of points to each variable (Table 19-1).

In 1989, Gramling studied a different sample of 40 successful and 40 unsuccessful Class II malocclusion corrections.[36] After this study, he changed the "successful" FMA range of 18 to 35 degrees to 22 to 28 degrees (Table 19-2).

Using information from the previously described clinical research, the craniofacial analysis (Table 19-3), 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. 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 proper proportion, correction of the

TABLE 19-2 The Probability Index after the Pretreatment Range for the Frankfort Mandibular Plane Angle Was Adjusted Downward to 22 to 28 Degrees

	Point Value	Cephalometric Value	Probability Index
FMA 22–28 degrees	5	—	—
ANB ≤6 degrees	15	—	—
FMIA ≥60 degrees	2	—	—
Occlusal plane ≤7 degrees	3	—	—
SNB ≥80 degrees	5	—	—
Total			—

ANB, Subspinale-nasion-supramentale angle; FMA, Frankfort mandibular plane angle; FMIA, Frankfort mandibular incisor axis angle; SNB, sella-nasion-supramentale angle.

TABLE 19-3 Craniofacial Analysis

Normal Range	Cephalometric Value	Difficulty Factor	Difficulty
FMA 22–28 degrees	—	5	—
ANB 1–5 degrees	—	15	—
Z angle 70–80 degrees	—	2	—
Occlusal plane 8–12 degrees	—	3	—
SNB 78–82 degrees	—	5	—
FHI (PFH-AFH) 0.65–0.75	—	3	—
Craniofacial difficulty total			—

AFH, Anterior facial height; ANB, subspinale-nasion-supramentale angle; FHI, facial height index; FHI = AFH/PFH; FMA, Frankfort mandibular plane angle; FMIA, Frankfort mandibular incisor axis angle; PFH, posterior facial height; SNB, sella-nasion-supramentale angle.

malocclusion is more 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 is 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 nonskeletal measurement in the craniofacial analysis. The Z angle was included because it is a facial reflector of craniofacial imbalance.

Dental Disharmony

Total Dentition Space Analysis

Along with a consideration of the face and the skeletal pattern, the orthodontist must consider the dentition (Table 19-4). Total space analysis as described by Merrifield[13] 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

TABLE 19-4 Total Space Analysis

Area	Value	Difficulty Factor	Difficulty
Anterior			
Tooth arch discrepancy	—	1.5	—
Head film discrepancy	—	1.0	—
Total	—		
Midarch			
Total arch discrepancy	—		
Curve of Spee	—		
Total	—		
Occlusal disharmony (Class II or Class III)	—	2	—
Posterior			
Tooth arch discrepancy	—		
Expected increase (–)	—		
Total	—	0.5	—
Space analysis total	—	Space analysis difficulty total	—

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. Tweed's cephalometric discrepancy is used to further analyze this area. The 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 the 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. The midarch is an important area of the dentition. Careful analysis of this area may show mesially inclined first molars, rotations, spaces, a deep curve of Spee, cross-bites, missing teeth, habit abnormality, blocked-out teeth, tooth size discrepancies, and occlusal disharmonies. 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 must also be recorded. To this value is added the space required to level the curve of Spee.[37] From these measurements, the orthodontist can determine the space deficit or surplus in this area.

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

Occlusal disharmony is best 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 embrasure as a reference. Measure mesially to the embrasure between the maxillary first premolar buccal cusp to the embrasure between the mandibular first and second premolars. This measurement is made on both sides and is then averaged to determine the

occlusal disharmony. The difficulty factor for occlusal disharmony is 2, so the averaged disharmony 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 an immature patient. It is a linear measurement in millimeters of the space distal to the mandibular first molars. 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, 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 unpredictable variables must be considered in estimating the increase in posterior available space. These variables are the following:

1. Rate of mesiocclusal 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[38-40] reveals that the consensus from researchers suggests that 3 mm of increase per year occurs in the posterior dentition area until age 14 years for girls and age 16 years for boys. This is an increase of 1.5 mm per year on each side of the arch after the complete eruption of the first molars. In a 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 because it gives the clinician the ability to know whether a surplus or deficit of space exists in this area.

To create a posterior discrepancy while making adjustments in either the midarch or anterior area is not prudent. Equally imprudent is to not use a posterior space surplus to help alleviate midarch and anterior deficits. The most easily recognizable symptom of a posterior space deficit in a young patient is the late eruption of the second molars. If space is not available for these teeth by the age of their normal eruption, it should be obvious that a posterior space problem exists. The posterior space analysis surplus or deficit has been given a low difficulty factor of 0.5 because a posterior space deficit can be easily resolved with 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 19-5). 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 the *total difficulty*. This value gives the clinician a quantitative method of evaluating the difficulty of correction for 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 other cephalometric values must be duly noted, evaluated by the orthodontist, and factored into any diagnosis. The orthodontist must also evaluate the patient's motivation and desire for correction of the malocclusion. 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.

TWEED-MERRIFIELD EDGEWISE APPLIANCE

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 must also be hygienic and aesthetic and, above all, have a wide range of versatility. The neutral 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 (Fig. 19-23).

All bands have lingual cleats attached. Lingual cleats 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 tip, torque, or variations in thickness are present in the bracket. A slot size of 0.022 allows the clinician to use a multiplicity of archwire dimensions.

Archwires

Resilient edgewise archwire 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, 0.019 × 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 archwire at the appropriate time.

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

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

First-Order Bends

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

TABLE 19-5 Differential Diagnostic Analysis System

CRANIOFACIAL ANALYSIS

Normal Range	Cephalometric Value	Difficulty Factor	Difficulty
FMA 22–28 degrees	—	5	—
ANB 1–5 degrees	—	15	—
Z angle 70–80 degrees	—	2	—
Occlusal plane 8–12 degrees	—	3	—
SNB 78–82 degrees	—	5	—
FHI (PFH-AFH) 0.65–0.75	—	3	—
Craniofacial difficulty total	—		—

TOTAL SPACE ANALYSIS

	Value	Difficulty Factor	Difficulty
Anterior			
Tooth arch discrepancy	—	1.5	—
Head film discrepancy	—	1.0	—
Total	—		—
Midarch			
Tooth arch discrepancy	—	1.0	—
Curve of Spee	—	1.0	—
Total	—	2.0	—
Occlusal disharmony (Class II or Class III)	—		—
Posterior			
Tooth arch discrepancy	—		—
Expected increase (–)	—	0.5	—
Total	—	Space analysis difficulty total	—
Space analysis total	—		
Craniofacial difficulty total	—		
Space analysis difficulty total	—		
Total difficulty	—		

AFH, Anterior facial height; ANB, subspinale-nasion supramentale angle; FHI, facial height index, FHI = AFH/PFH ; FMA, Frankfort mandibular plane angle; PFH, posterior facial height; SNB, sella-nasion supramentale angle.
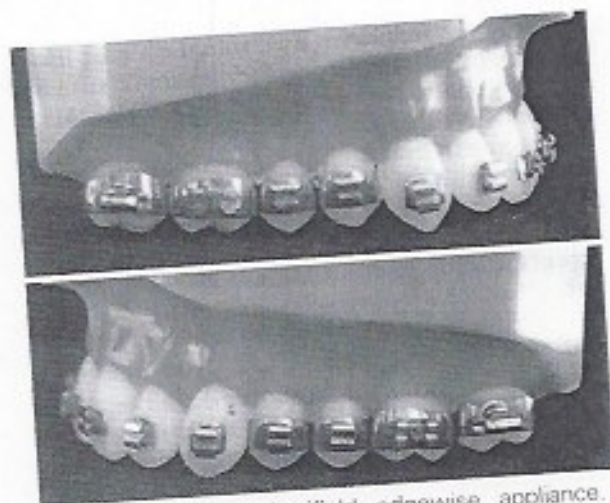

FIGURE 19-23 Tweed-Merrifield edgewise appliance. The appliance is composed of neutral 0.022-inch edgewise slots with double-width brackets on the six anterior teeth, intermediate single-width brackets on the premolar bands, twin brackets on the first molars, and 0.022-inch tubes with mesial hooks on the second molars.

Second-Order Bends

Second-order bends in the posterior segment of the mandibular archwire 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 archwire also negatively affect the third-order position of the mandibular anterior teeth. Therefore, the mandibular anterior teeth generally require lingual crown torque in the archwire because posterior second-order tipping bends apply labial crown torque force to the incisors. This fact must be given careful consideration in archwire 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 forces intrudes the maxillary incisors and gives a lingual root torque effect to these teeth. This is generally positive or complementary to treatment objectives.

Third-Order Bends

Third-order bend reaction in the mandibular archwire is complementary to all the teeth if properly placed. The objective is

have some degree of lingual crown torque on all the mandibu-lar teeth. The posterior and anterior segments work together in action, reaction, and interaction. The ideal third-order bends (lingual crown torque) in the mandibular archwire are as fol-lows: incisors, 7 degrees; canines and first premolars, 12 degrees; and second premolars and molars, 20 degrees.

Conversely, third-order bends in the maxillary archwire are antagonistic. The anterior segment needs no torque (0 degrees), or it needs 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 third-order force simultaneously in segments with oppo-site third-order requirements is not wise. In the maxillary arch, applying active third-order 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. Patient compliance with auxiliaries is imperative.

Variations of the Appliance

Many variations of the edgewise appliance have been intro-duced in the past 30 years. Most notable of the variations is the "straight wire" appliance (SWA) introduced in 1972 by Larry Andrews.[4] The SWA 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 archwire. Another variation in the standard appliance is a decrease in slot size from 0.022 to 0.018 inch and even to 0.016 inch. Various orthodontic suppliers market numerous varia-tions of the SWA with different tips and torques to suit the individual operator's desires. Other modifications have been extensively described by Burstone,[42] Lindquist,[43] and Roth.[44]

TREATMENT WITH THE TWEED-MERRIFIELD EDGEWISE APPLIANCE

Any treatment protocol must complement a diagnostic phi-losophy. Using Tweed's treatment concepts as a foundation, Merrifield developed force systems that simplify the use of the edgewise appliance. For example, Tweed used 12 sets of archwires during the treatment of each patient. Today, with the modern edgewise appliance, only three to five sets of archwires are used. Merrifield's sequential directional force technology[45-47] is simple, straightforward, and funda-mentally sound. From the era of Tweed and into the era of Merrifield, the key to quality treatment with the edgewise appliance continues to be directionally controlled precision archwire manipulation. Essentially, five concepts compose the treatment philosophy: (1) sequential appliance place-ment; (2) sequential or individual tooth movement (or both); (3) sequential mandibular anchorage preparation; (4) direc-tional forces, including control of the vertical dimension to enhance a favorable mandible to maxilla spatial change; 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 archwire or are ligated passively. This method of sequential appli-ance 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 archwire during the first months of treatment because it gives the posterior segment of the archwire much longer interbracket length. This length creates a power storage that accomplishes second molar move-ment 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 banded and bracketed teeth respond to the forces of the archwire 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. It is not the en masse movement that was introduced by Tweed. Individual teeth are moved rap-idly and with precision because they are moved singly 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 compen-sation bends were placed in the archwire at one time. Sequelae of this force system were often labially flared and intruded man-dibular incisors. Sequential mandibular anchorage preparation, developed by Merrifield, is a 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 and anterior vertical elastics rather than Class III elastics for support. Unlike the en masse anchorage of the Tweed era, movement is controlled, sequential, and precise.

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 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 correc-tion (Fig. 19-24). An upward and forward force system requires that the mandibular incisor be upright over basal bone so that the maxillary incisor can be moved properly (Fig. 19-25). 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 to a proper functional and aesthetic position (Fig. 19-26). The unfortunate result of point B dropping down and back is a patient with a lengthened face, a gummy smile, incompetent lips, and a more recessive chin.
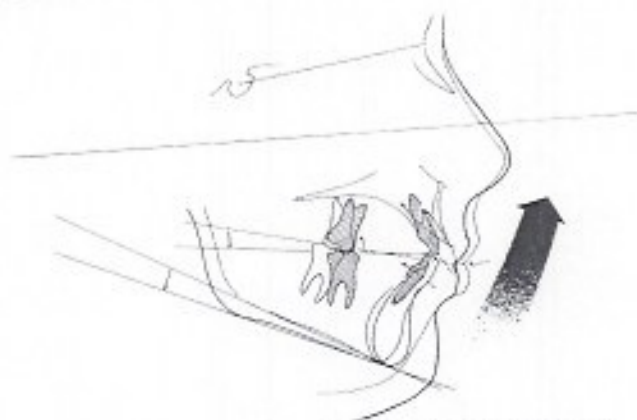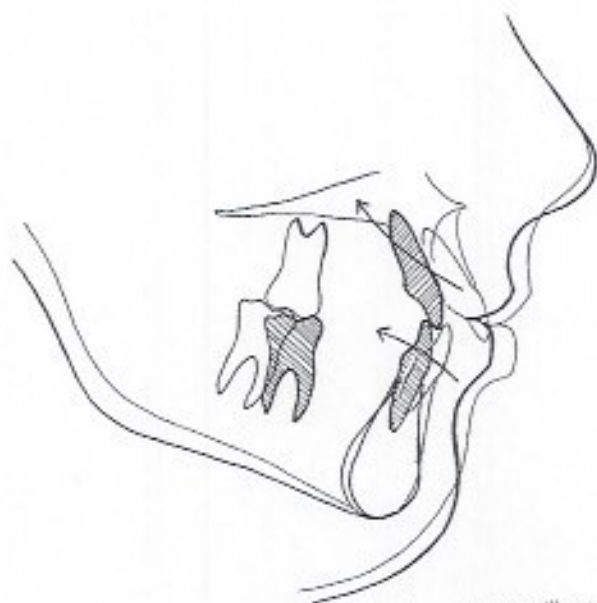
FIGURE 19-24 Upward and forward force system.

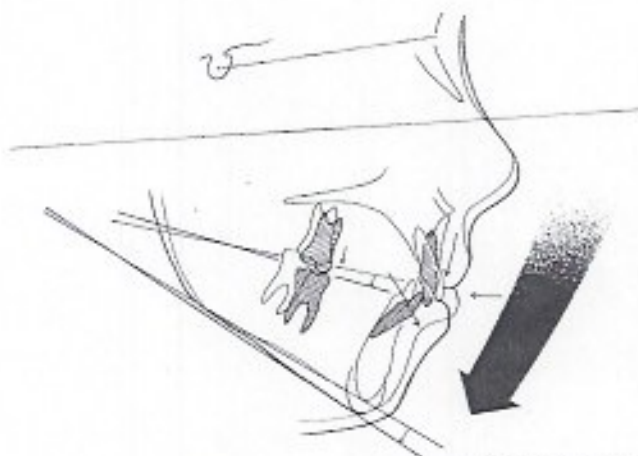**FIGURE 19-25** Upright mandibular incisor and maxillary incisor moved up and back.

FIGURE 19-26 Downward and backward force system.

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. This may mean interceptive treatment in the mixed dentition, selected extractions in the mixed dentition, or waiting for permanent second 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

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

The teeth of the original malocclusion are sequentially banded and bonded (Fig. 19-27). After the placement of the appliance, an 0.018- × 0.025-inch resilient mandibular archwire and a 0.017- × 0.022-inch resilient maxillary archwire are inserted. The omega loop stops are flush against the second molar tubes in each arch. The mandibular second molar receives an effective distal tip that will upright its mesial inclination. In the maxillary arch, a 20-degree tip is placed in the wire distal to the omega loop stop to maintain the distal inclination of the second molar. The objective in each respective arch is to maintain the maxillary molar in its distally tipped position and to begin to distally tip the mandibular second molar enough to level it into the arch.

A second premolar offset bend is placed mesial to the second premolar bracket in each archwire. The purpose of this bend is to prevent the canines from expanding labially as they are retracted with the headgear. The third-order bends in each
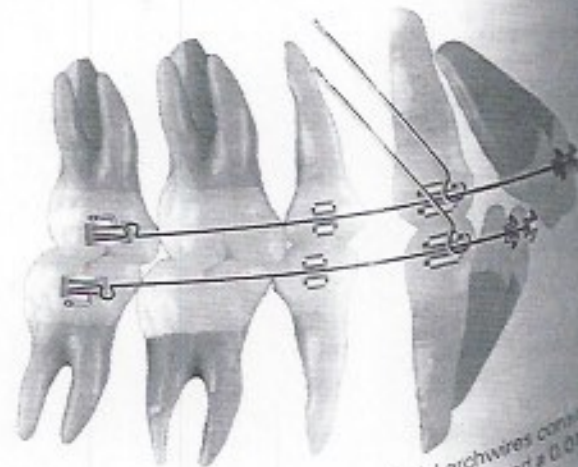

FIGURE 19-27 Denture preparation: Initial archwires consist of a 0.017- × 0.022-inch resilient maxillary archwire and a 0.018 × 0.025-inch resilient mandibular archwire.

archwire are ideal. High-pull J-hook headgear is used to retract maxillary and mandibular canines. 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 (Fig. 19-28).

One must remember that at each visit during denture preparation, the archwires 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 retracted, all rotations should be corrected, and the mandibular second molars should be level (Fig. 19-29).

Denture Correction

The second step of treatment is called denture correction. During denture correction, the spaces are closed with maxillary and mandibular closing loop archwires. Vertical support to the maxillary arch is achieved with J-hook headgear attached to hooks soldered to the maxillary archwire between the maxillary central and lateral incisors. Vertical support of the mandibular anterior teeth is accomplished with anterior vertical elastics. The mandibular archwire is a 0.019- × 0.025-inch working archwire with 7.0-mm vertical loops distal to the lateral incisor brackets. The 0.020- × 0.025-inch maxillary archwire has 7.5-mm vertical loops distal to the lateral incisor brackets. In both arches, the omega loop stops are immediately distal to the brackets of the first molars (Fig. 19-30). The maxillary archwire is coordinated with the mandibular archwire. The archwires are activated each month until all space is closed. At the end of space closure (Fig. 19-31), the curve of occlusion in the maxillary arch should have been maintained, and the mandibular

FIGURE 19-30 Denture correction: Maxillary and mandibular closing loops are used to close the space mesial to the distalized canines.
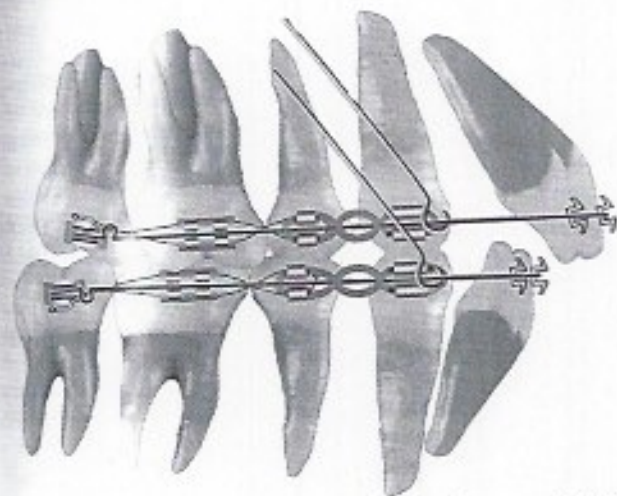

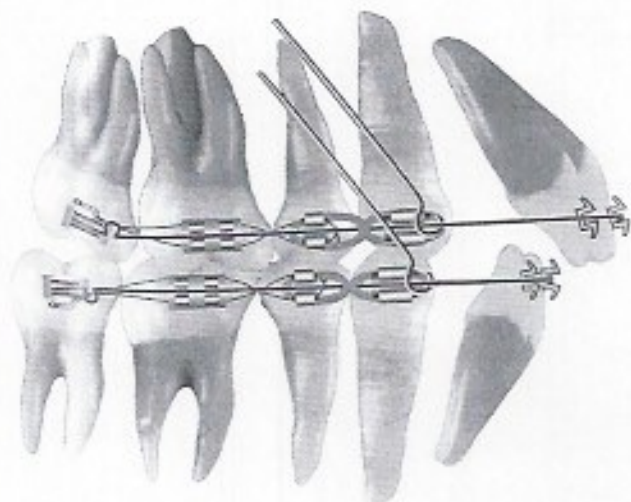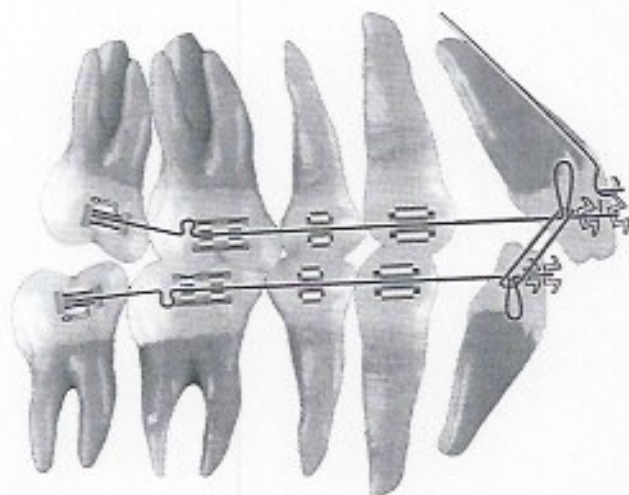FIGURE 19-28 Denture preparation: The canines are retracted with a J-hook headgear during denture preparation.

FIGURE 19-29 Denture preparation: At the end of denture preparation the arches are level, rotations are corrected, and the canines are retracted.
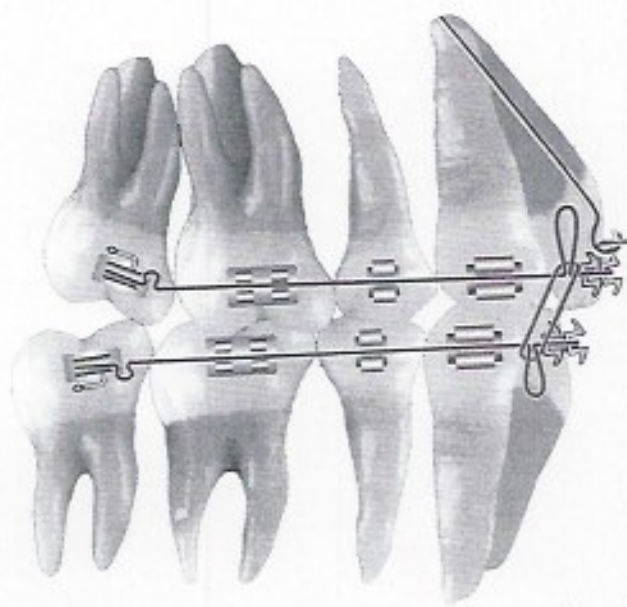

FIGURE 19-31 Space closure. The arches are level, and all spaces are totally closed.

arch should be completely level. 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 archwire produces an active force on only two teeth while remaining passive to the other teeth in the arch. Therefore, the remaining teeth act as stabilizing or anchorage units as two teeth are tipped. The method is referred to as the "10-2" (10 teeth vs. 2 teeth) anchorage system, and it allows a quickly controlled response without serious adverse reaction. The anchorage preparation system is supported by anterior vertical elastics attached to spurs that are soldered distal and gingival to the mandibular lateral incisors. The elastics are hooked to the closing loops of the maxillary archwire. They are supported by a high-pull headgear that is attached to hooks soldered to the maxillary archwire.

After closing the mandibular space, the mandibular arch must be level. At this time, the first step of sequential mandibular anchorage preparation, second molar anchorage, is initiated. Another 0.019- × 0.025-inch archwire with the omega loop stops bent flush against the second molar tubes is fabricated. First- and third-order bends are ideal. Gingival spurs for anterior vertical elastics are soldered distal to the lateral incisors.

To tip the mandibular second molars to an anchorage prepared position, a 15-degree tip is placed distal to the omega loop stop. The second molar is tipped to an anchorage prepared position. It should have a distal inclination of 10 degrees to 15 degrees, which can be verified with a readout (Fig. 19-32, A).[48]

After the second molar has been tipped, the first molar is tipped to its anchorage prepared position by placing a 10-degree distal tip 1 mm mesial to the first molar bracket. When this first molar tip is placed in the archwire, a compensating bend

that maintains the 15-degree second molar inclination must be placed mesial to the omega loop stop (Fig. 19-32, B).

The archwire is now passive to the second molar and crosses the twin brackets of the first molar at a 10-degree bias. The second molars are now part of the 10 stabilizing units, and the first molars are the two teeth that receive the action of the directional forces and the archwire. After 1 month, the archwire is removed, and a readout should show a 5- to 8-degree distal inclination of the first molars. The second molars should continue to read out at 15 degrees.

The denture correction step of treatment should now be complete for the Class I malocclusion. The objectives of the denture correction step are (1) complete space closure in both denture correction step are (2) sequential anchorage preparation in the mandibular 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 mesiobuccal groove of the mandibular first molar. The distal cusps of these teeth should be discluded, as should the second molars.

Class II Force System

For patients with an "end-on" Class II dental relationship of the buccal segments at the conclusion of space closure, a new force system must be used to complete the denture correction stage of treatment. A careful study of the cusp relationships will determine the force system required. Making a final diagnostic decision for Class II correction is usually 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
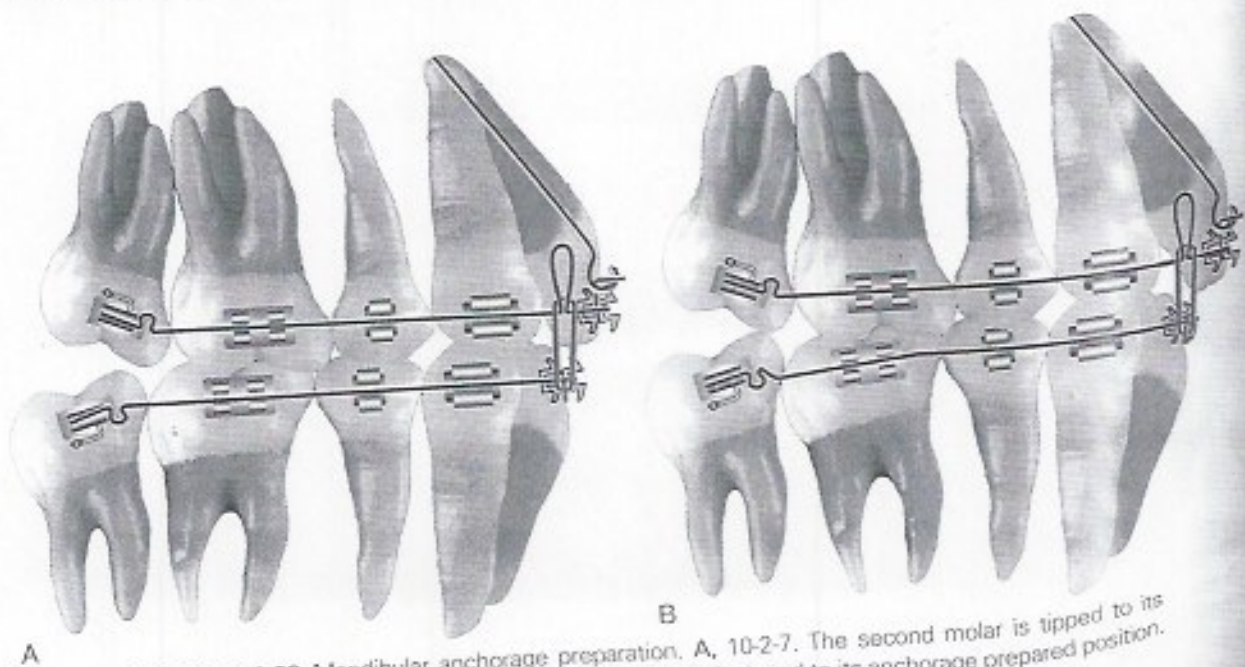

FIGURE 19-32 Mandibular anchorage preparation. A, 10-2-7. The second molar is tipped to its anchorage prepared position. B, 10-2-6. The first molar is tipped to its anchorage prepared position.

degrees), (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 dentition into the second molar extraction space.

3. If (a) the ANB is approaching 10 degrees, (b) maxillary third molars are present, (c) there is a full step Class II molar occlusion, or (d) the patient's motivation is questionable, the first molars may be considered for removal after the maxillary and mandibular first premolar has been closed. Surgical correction may also be considered. Facial balance and harmony "projections" after correction with either molar extraction or orthognathic surgery 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.

Orthodontic Correction of the Class II Dental Relationship

At the end of sequential mandibular anchorage preparation, a mandibular 0.0215- × 0.028-inch stabilizing archwire is fabricated. Ideal first-, second-, and third-order bends are incorporated into the archwire. The omega 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.

A 0.020- × 0.025-inch maxillary archwire with 7.5-mm closed helical bulbous loops bent flush against the second molar tubes is fabricated. The helix is wound to the lingual during fabrication. This archwire has ideal first- and second-order bends. The molar segment has 7 degrees of progressive lingual crown torque. A gingival spur is attached to the archwire immediately distal to the maxillary second premolar bracket. 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. Before archwire insertion, the closed helical bulbous loops are opened 1 mm on each side. The anterior segment of the archwire will be 1 mm labial to the maxillary incisor brackets. The archwire is ligated in place. Class II elastics are worn from the hooks on the mandibular second molar tubes to the Class II hooks on the maxillary archwire. Anterior vertical elastics are worn from the spurs on the mandibular archwire to the gingival extension hooks on the maxillary archwire. The high-pull headgear is worn on the maxillary headgear hooks (Fig. 19-33, A).

This force system is used to sequentially move the maxillary second molars distally. At each appointment, the mandibular archwire is removed and checked, and the helical bulbous loops are activated 1 mm. The activation of the maxillary archwire is repeated until the second molars have a Class I dental relationship (Fig. 19-33, 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 when the maxillary archwire is inserted. (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 chain create a distal force on the maxillary first molar. Additionally, a Class II elastic is worn continuously from the mandibular second molar hook to the Class II hook on the maxillary archwire. An anterior vertical elastic is worn 12 hours each day (Fig. 19-34). The high-pull headgear is worn 14 hours per day on the spurs soldered to the maxillary archwire. This is an efficient force system for first molar distalization (Fig. 19-35).

After the first molars have been 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 (Fig. 19-36). Four months
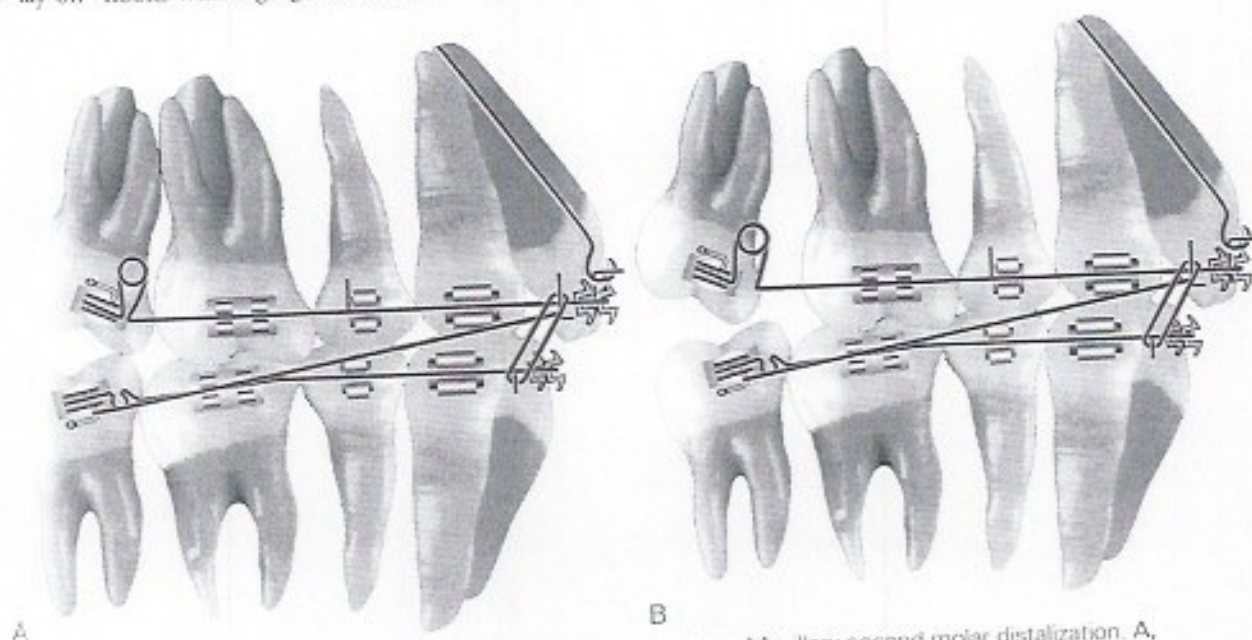

FIGURE 19-33 Denture correction: Class II force system. Maxillary second molar distalization. A, Step 1. A helical bulbous loop is placed against the maxillary second molar. B, Step 2. The helical bulbous loop pushes the maxillary molar distally to a Class I relationship.

of treatment with monthly reactivation should position the posterior teeth and the maxillary canine in an overtreated Class 1 relationship. This system will not strain the mandibular arch if the anterior vertical elastics are worn and if sufficient space is available in the maxillary posterior denture area.

After overcorrection of the Class II dental relationship, a 0.020- × 0.025-inch maxillary archwire with 7.5-mm closing loops distal to the lateral incisors is fabricated. This archwire has ideal first-, second-, and third-order bends. Gingival headgear hooks are soldered distal to the central incisors (Fig. 19-37). The closing loops are opened 1 mm per visit by cinching the omega loop stops to the molar tube. Class II elastics, anterior vertical elastics, and the maxillary high-pull headgear are used. After all the maxillary space is closed, the denture correction step of treatment has been completed. The dentition is ready for the next step of treatment—denture completion.
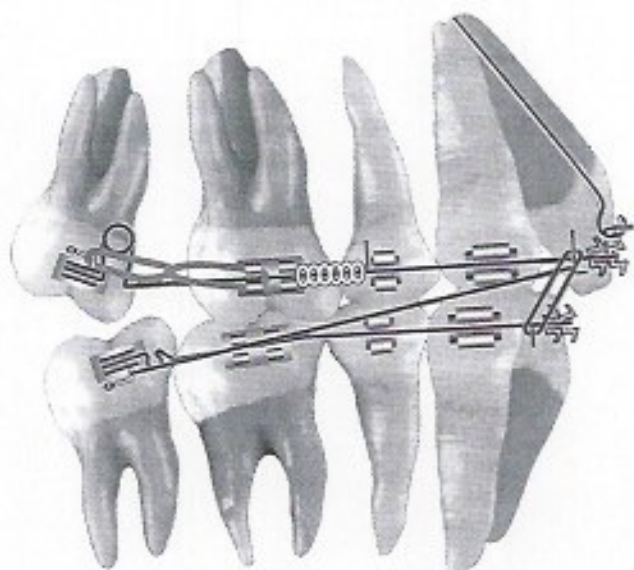
Denture Completion

The third step of treatment is identified as denture completion. Ideal first-, second-, and third-order bends are placed in finishing mandibular and maxillary 0.0215- × 0.028-inch resilient archwires. The mandibular archwire duplicates the previously used mandibular stabilizing archwire. The maxillary archwire 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 (Fig. 19-38).

The forces used during denture completion are based on a careful study of the arrangement of each tooth in each arch. The orthodontist must also study the relationship of one arch to the other and the relationship of the arches to their environment. The orthodontist makes necessary first-, second-, and third-order adjustments in each archwire as needed. A progress cephalogram and tracing

FIGURE 19-34 Denture correction: Class II force system. A coil spring is trapped mesial to the first molar.

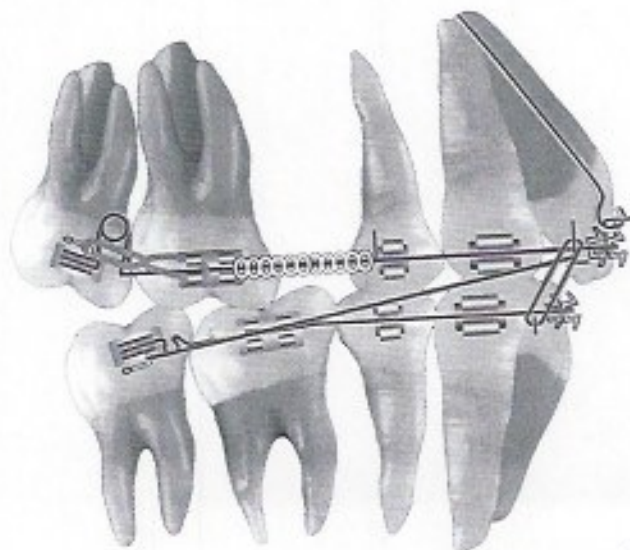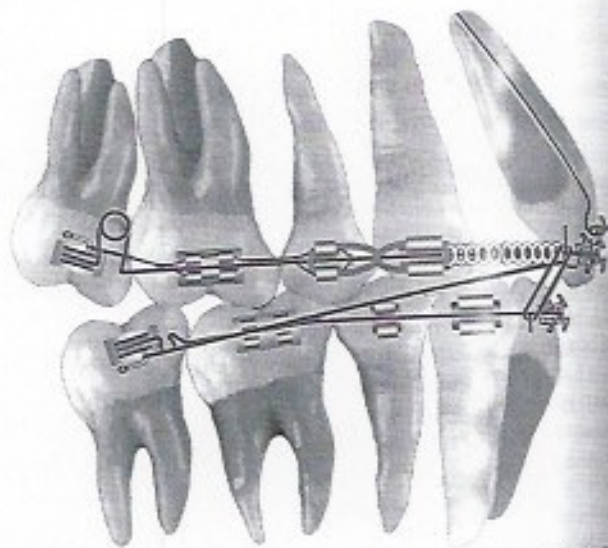FIGURE 19-36 Denture correction: Class II force system. Maxillary second premolar and maxillary canine distalization. After molar distalization the premolars and canines are distalized.

FIGURE 19-35 Denture correction: Class II force system. Maxillary first molar distalization.
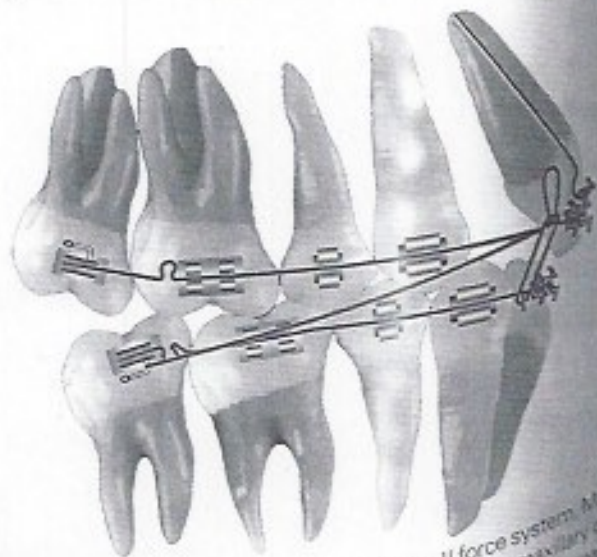

FIGURE 19-37 Denture correction: Class II force system. Maxillary anterior space closure. A 0.020- × 0.025-inch maxillary closing loop archwire is used to close the maxillary anterior space.

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 cephalogram may also 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 minitreatment of the malocclusion. During this treatment step, the orthodontist uses the forces that are necessary until the original malocclusion is overcorrected.

Denture Recovery

An ideal occlusion will be present only after all treatment mechanics are discontinued and uninhibited function and other environmental influences active in the posttreatment 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 corrective 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.

The posttreatment occlusion, which is carefully planned, sometimes referred to as Tweed occlusion but properly identified as transitional occlusion (Fig. 19-39), 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 intruded distally inclined maxillary and mandibular second molars now can "reerupt" to a healthy functional occlusion
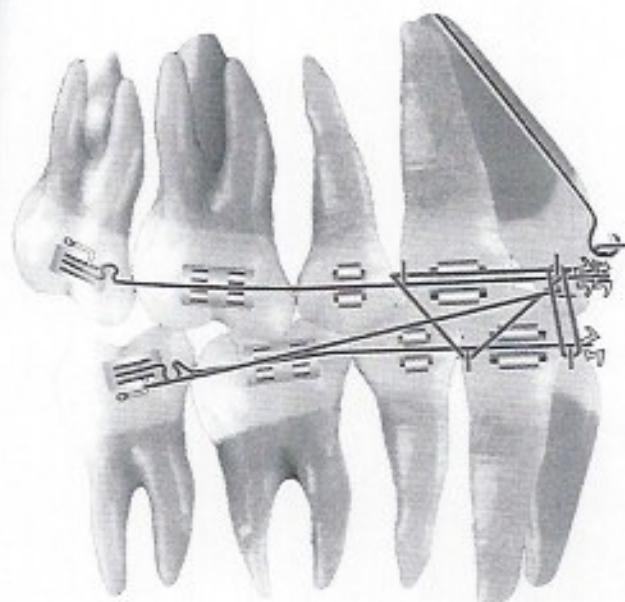
without trauma or premature contact. Because of overtreatment of Class I and Class II deep-bite patients, the anterior teeth are positioned in an end-to-end relationship with no overbite or overjet. This relationship, however, is transitory and will adjust rapidly to an ideal overjet and overbite relationship (Fig. 19-40).

The correction of two malocclusions will be illustrated. These patients were treated with the Tweed-Merrifield edgewise appliance. The reason for showing the records of these patients is to illustrate that all treatment objectives can be routinely attained in the treatment of different types of malocclusions if the force
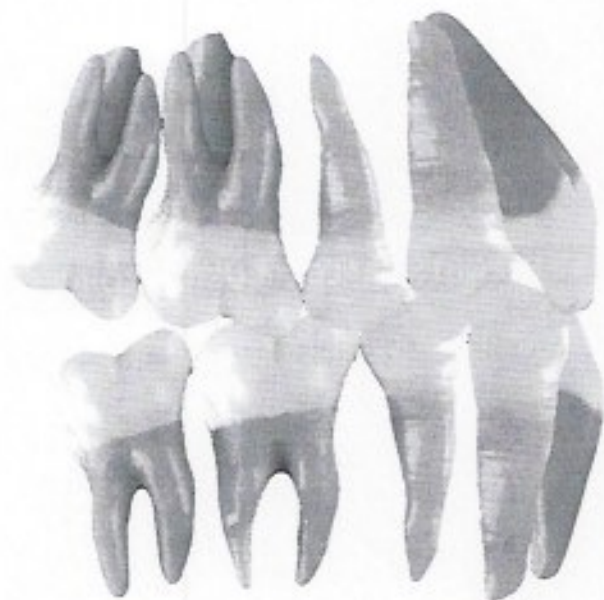

FIGURE 19-39 Transitional occlusion: The occlusion must be overtreated. The anterior teeth should be edge to edge. The canines, second premolars, and first molars should have a solid Class I dental relationship. The second molars should be tipped out of occlusion.

FIGURE 19-38 Denture completion: Maxillary and mandibular stabilizing archwires, along with the proper elastics and headgear force, are used to complete the orthodontic treatment.
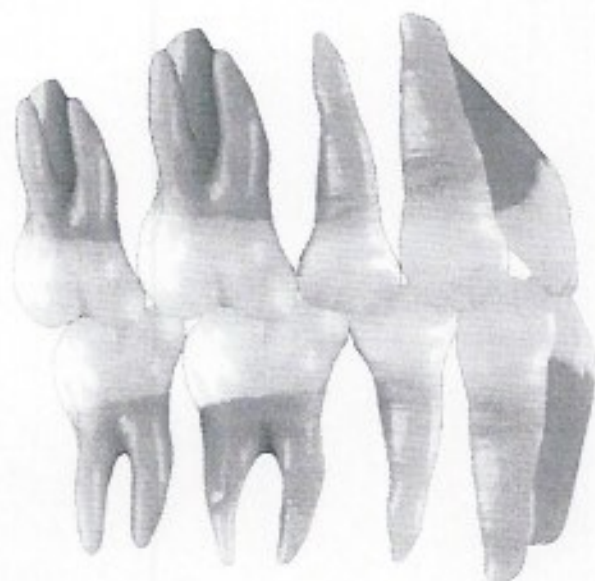

FIGURE 19-40 Final occlusion is characterized by the teeth settling into their most efficient, healthy, and stable positions.

system that has been presented is used. The diagnosis of the first malocclusion is described in detail to illustrate the use of the craniofacial analysis and the total dentition space analysis for making the differential diagnosis from which the treatment plan is formulated. This first malocclusion was a protruded Class II, division I subdivision malocclusion with facial imbalance. The force system used to correct the malocclusion was the Class II force system previously described in this chapter.

SUMMARY

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 use of the appliance evolved with Levern Merrifield over many more years. He introduced the following: (1) differential diagnosis, which led to the removal of the teeth that would best produce balance, harmony, and facial proportion within the cranial–facial complex; (2) directional force technology; and (3) sequential archwire manipulation. The edgewise appliance is a precise instrument for the routine correction of major malocclusions. Although the Tweed-Merrifield edgewise appliance is the direct descendent of the appliance invented in 1928 by Edward H. Angle, it is used with a totally different philosophy of treatment. A consistent effort is being continuously directed toward its further sophistication. The edgewise appliance has stood the test of time and will be used in the future by many more generations of orthodontists.

CASE REPORTS: MALOCCLUSION CORRECTION WITH THE EDGEWISE APPLIANCE

Patient 1: NY
This 12-year-old boy shows a malocclusion with facial, dental, and craniofacial disharmony.

Profile and full face photographs (Fig. 19-41) illustrate the protrusion and the facial imbalance. The casts (Fig. 19-42) exhibit an Angle Class II end-to-end occlusion on the right, a deep impinging overbite, and flared and protrusive maxillary and mandibular incisors. The pretreatment cephalogram and its tracing (Fig. 19-43) illustrate an ANB of 7 degrees and an AO-BO

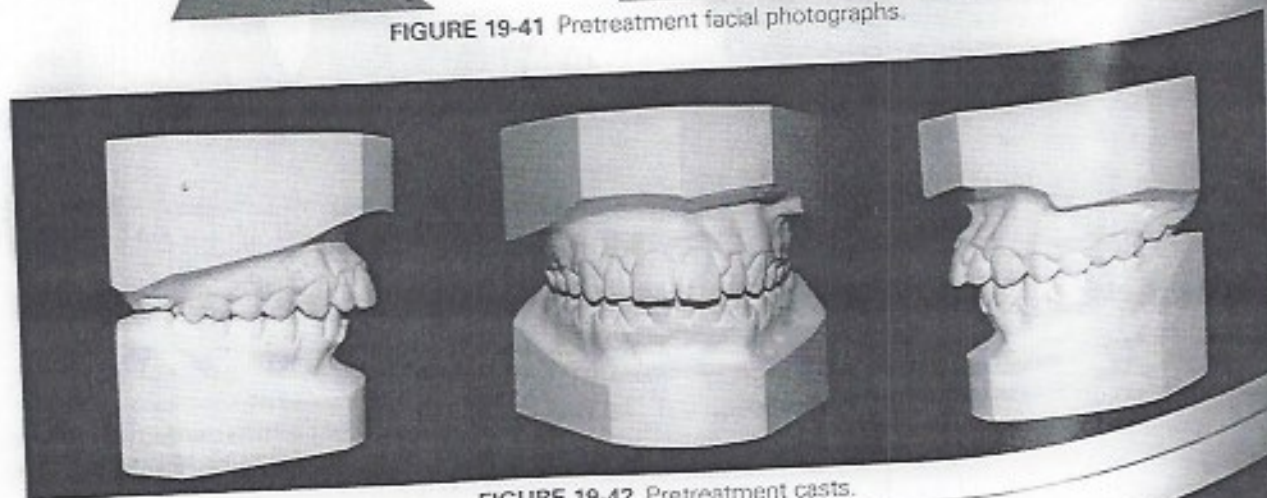FIGURE 19-41 Pretreatment facial photographs.

FIGURE 19-42 Pretreatment casts.

of 14 mm, both of which are indicators of the severity of the malocclu- sion. The FMIA of 58 degrees and the Z angle of 63 degrees reflect the protrusive face. Mandibular incisors are flared. The differential diagnostic analysis system was used to give some objectivity to the patient's skele- tal, dental, and facial problems. The craniofacial analysis shows a cranio- facial difficulty total of 71.0. The SNB is lower than normal. The ANB is larger than normal. The facial protrusion needs to be corrected. The total

dentition space analysis reflects the protrusion in the anterior dentition area with a cephalometric correction discrepancy factor of 9.6, a curve of Spee of 2.5 mm, and a 5-mm Class II occlusal issue. The total anterior dis- crepancy difficulty was 14.1 mm, the midarch and the occlusal disharmony discrepancy was 12.5 mm, and the posterior discrepancy was 9 mm. The space analysis difficulty was 35.6 mm. Total dentition difficulty was 106.6 (Fig. 19-44).
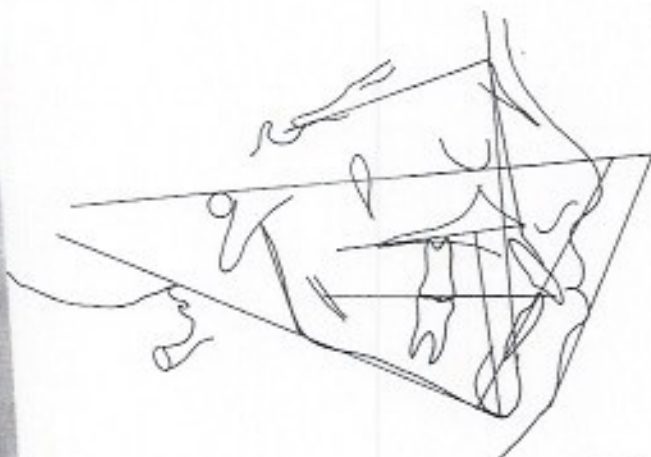
FMIA	56
FMA	28
IMPA	96
SNA	83
SNB	76
ANB	7
AO-BO	4 mm
OP	5
Z	62
UL	12 mm
TC	11 mm
PFH	40 mm
AFH	62 mm
FH6	0.64

FIGURE 19-43 Pretreatment cephalogram and cephalometric tracing. See Figure 19-13 for abbreviations.

Cranial Facial Analysis

	Cephalometric Value	Difficulty Factor	Difficulty
Normal Range			0
FMA 22–28	28	5	30
ANB 1–5	7	15	16
Z angle 70–80	62	2	12
Occusal plane 8–12	4	3	10
SNB 78–82	76	5	3
PFH/AFH 0.65–0.75	0.64	3	
		Craniofacial Difficulty Total	71

Total Space Analysis

	Value	Difficulty Factor	Difficulty
Anterior			
Tooth arch discrepancy	3.0	1.5	4.5
Headfilm discrepancy	9.6	1.0	9.6
Total	12.6		14.1
Midarch			0.0
Tooth arch discrepancy	0.0	1.0	2.5
Curve of Spee	2.5	1.0	2.5
Total	2.5		
Horizontal occlusal disharmony (Class II or III)	5.0	2.0	10.0
Posterior			
Tooth arch discrepancy	20.0		
(−)Expected increase	12.0		
Total	18.0	.5	9.0
		Space Analysis	
Space analysis total	35.6	Difficulty total	35.6

Craniofacial difficulty total	71.0
Space analysis difficulty total	35.6
Total difficulty	106.6

Difficulty Index: mild, 0 to 60; moderate, 60 to 120; severe, 120+.

FIGURE 19-44 Total dentition difficulty analysis. See Figure 19-13 for abbreviations.

504

Because of facial and dental protrusion and the immediate need to upright the mandibular incisors, 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 correction was completed with 22 months of active appliance therapy. The patient's posttreatment facial photographs (Fig. 19-45), when compared with the pretreatment photographs, exhibit a significant and positive change in facial balance. The protrusion no longer exists, and the patient has a pleasing profile. The posttreatment casts (Fig. 19-46) exhibit control of the dentition and creation of an ideal Angle Class 1 dental relationship on the right side. Some distal tipping of the mandibular molars should be noted. These teeth have been tipped out of occlusion because of the anchorage preparation that enhanced vertical control during the Class II elastic wear. Arch form has been maintained. The posttreatment cephalogram and tracing (Fig. 19-47) illustrate changes in many of the cephalometric values. FMIA increased from 56 degrees to 69 degrees. IMPA decreased from 96 degrees to 84 degrees. The Z angle increased from 63 degrees to 78 degrees. These values are clear indications that the goals for facial balance and harmony were met. Superimposition tracings (Fig. 19-48) 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 the spatial change of the mandible in relation to the maxilla was downward and forward. This downward and forward change contributed greatly to the improved facial balance and harmony. The smiling photographs of the patient (Fig. 19-49) confirm intrusion of the incisors and a considerably better smile with less gingival display.

Patient 2: CL

A patient whose treatment plan requires the extraction of maxillary first premolars and mandibular second premolars generally has the following characteristics: (1) Balance and harmony of the lower face (Fig. 19-50) is within reasonable limits, or there is only a mild facial imbalance. In other words, these patients do not generally exhibit a great degree of unbalance of the lower face. (2) The dentition (Fig. 19-51) is most often a Class II dental relationship and mild mandibular and/or maxillary anterior crowding. Many of these patients have a protrusion of the maxillary anterior teeth. (3) The cephalometric examination of the skeletal pattern most often reveals a moderate mandibular plane angle, mandibular incisors that are "reasonably upright" over basal bone, and a discrepancy in the
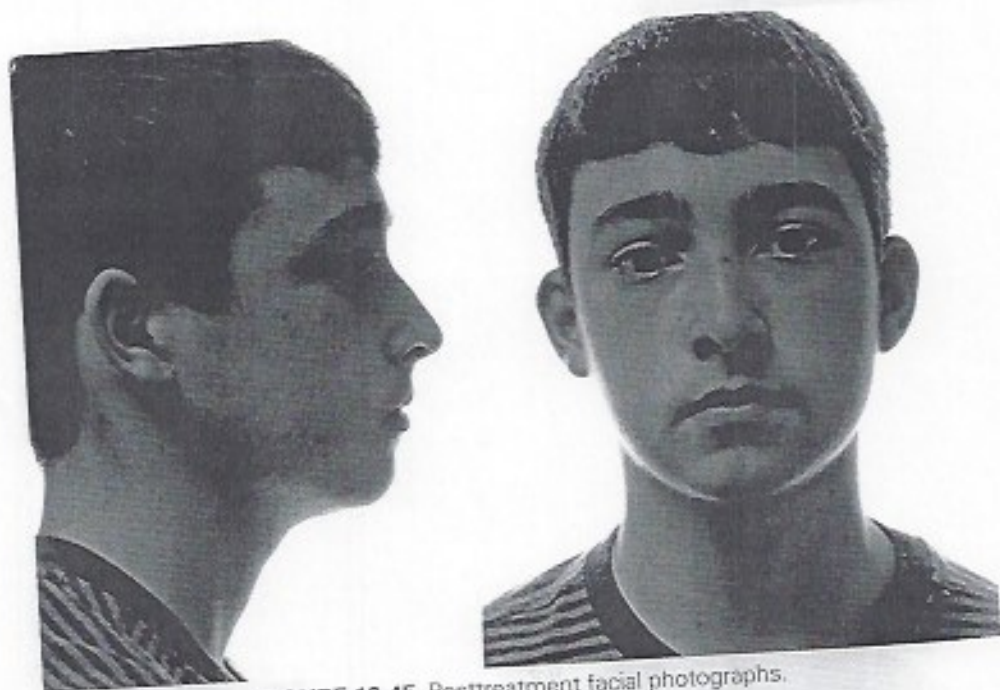

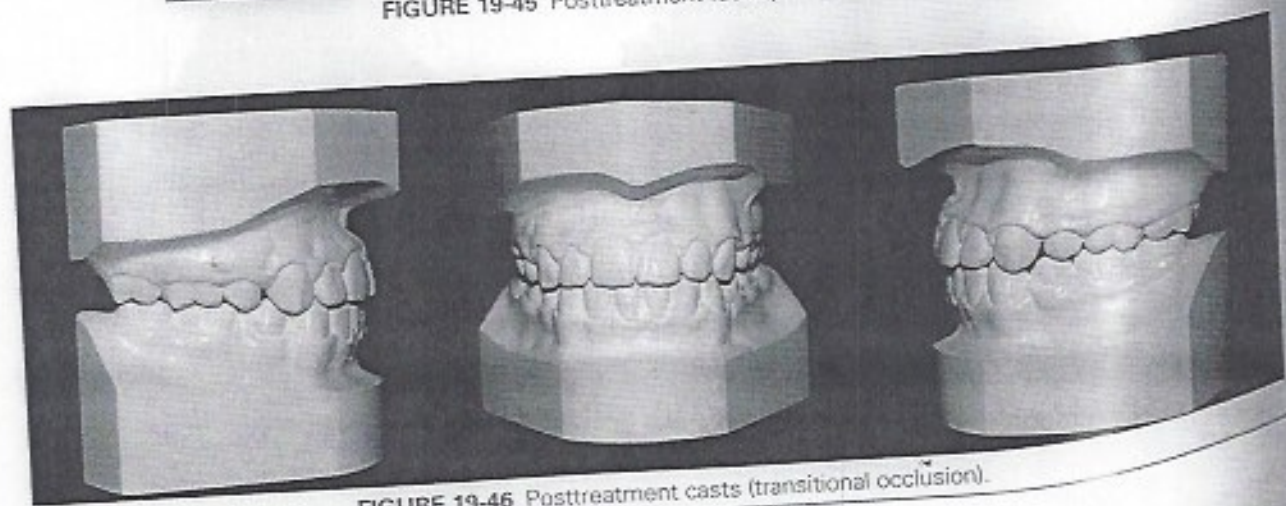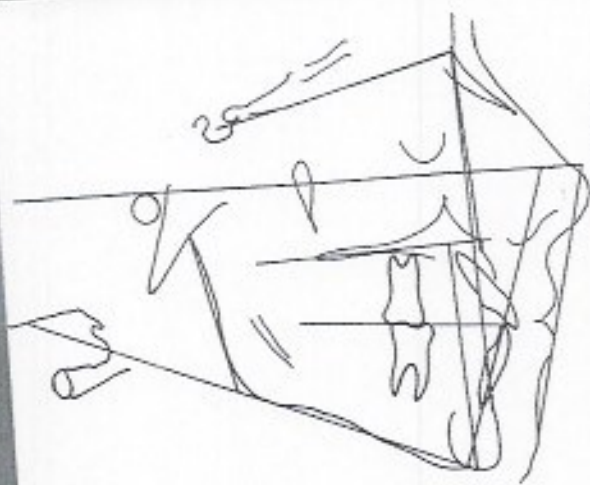FIGURE 19-45 Posttreatment facial photographs.

FIGURE 19-46 Posttreatment casts (transitional occlusion).

CASE REPORTS: MALOCCLUSION CORRECTION WITH THE EDGEWISE APPLIANCE—cont'd

FMIA	68
FMA	27
IMPA	87
SNA	79
SNB	77
ANB	2
AO-BO	0 mm
OP	5
Z	78
UL	15 mm
TC	12 mm
PFH	48 mm
AFH	67 mm
FHI	0.71

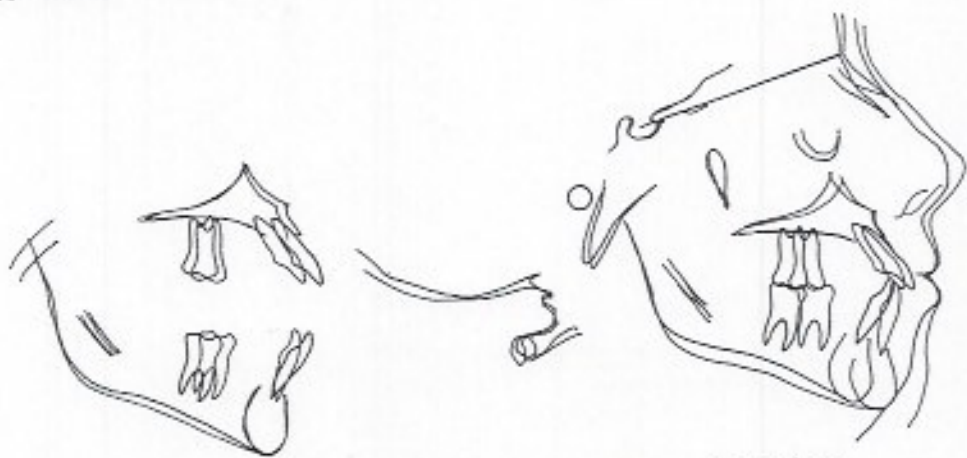FIGURE 19-47 Posttreatment cephalogram and cephalometric tracing. See Figure 19-13 for abbreviations.

FIGURE 19-48 Pretreatment–posttreatment superimpositions.

FIGURE 19-49 Pretreatment–posttreatment smiling photographs.

FIGURE 19-50 Pretreatment facial photographs.

FIGURE 19-51 Pretreatment casts.

anteroposterior relationship of the mandible to the maxilla. In our example, patient CL has an ANB of 7 degrees, an FMIA of 61 degrees, and an IMPA of 97 degrees (Fig. 19-52). These are values that one would expect for patients who "fit" into this facial, skeletal, and dental pattern.

When making the differential diagnosis, it is important to understand the relationship of the mandible to the maxilla and the relationship of the teeth to the face. In this particular example, the FMIA, Tweed's "facial angle," must be increased if the patient is to have improved balance and harmony in the lower face. Patient CL was treated with the extraction of the maxillary first premolars and the mandibular second premolars. The mandibular incisors were uprighted, the posterior occlusion was corrected by mesial movement of the mandibular posterior teeth, and crowding was ameliorated.

The mesialization of the mandibular first molar is accomplished with a variation of the mandibular archwires used during denture preparation (Fig. 19-53, A–D). This system is based on control of the mandibular anterior and posterior teeth as the second premolar extraction space is closed. As the mandibular first molar is protracted, the second molar drifts mesially. When all mandibular space is closed, the second molar is banded, mandibular anchorage is prepared, and treatment is finished with the archwire sequences that have been previously described.

The posttreatment facial photographs (Fig. 19-54) illustrate improvement in balance and harmony of the lower face. The chin is not as recessive. There is a nice curl in the maxillary lip and less eversion of the lower lip. The pretreatment–posttreatment casts (Fig. 19-55) confirm correction of the posterior occlusion and crowding amelioration. The posttreatment

cephalogram and cephalometric tracing (Fig. 19-56) confirm mild uprighting of the mandibular incisors, an increase in FMIA from 6 degrees to 66 degrees, maintenance of the mandibular plane angle, and reduction of the ANB from 7 degrees to 3 degrees because of retraction of point A. The superimpositions (Fig. 19-57) confirm a nice spatial change of the mandible in its relationship to the maxilla, vertical control of the molars, mild uprighting of the mandibular incisors, and intrusion and retraction of the maxillary incisors.

The correction of two distinctly different types of malocclusions has been illustrated. Both of these malocclusions were recently treated. The intent of showing NY's records is to illustrate the fact that all treatment objectives can be routinely obtained in the treatment of a difficult malocclusion if the force system that has been presented is used. The treatment planning of NY's malocclusion is described in detail to illustrate the use of the craniofacial analysis and the total dentition space analysis. This malocclusion was an Angles Class II, division I, subdivision, with facial imbalance. The Class II force system, which has been described in this chapter, was used on the patient's right side after all premolar extraction spaces had been closed. Because this patient was recently treated, his casts reflect the transitional occlusion that will settle into the final occlusion.

The second case report is presented to illustrate the carefully planned correction of a malocclusion that was treatment planned for the extraction of the maxillary first and mandibular second premolars. The treatment goal was to improve the mild facial imbalance and to correct the dental disharmony. The Tweed-Merrifield force system that was used to protract the mandibular first molars was described and illustrated
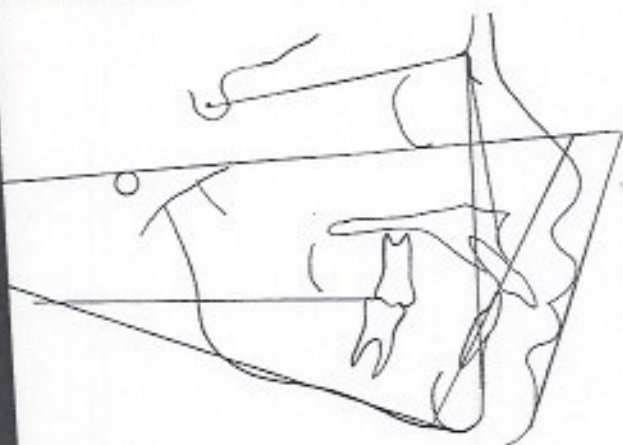
FMIA	61
FMA	22
IMPA	97
SNA	89
SNB	82
ANB	7
AO-BO	4 mm
OP	5
Z	67
UL	13 mm
TC	13 mm
PFH	44 mm
AFH	58 mm
FHI	0.75

FIGURE 19-52 Pretreatment cephalogram and cephalometric tracing. See Figure 19-13 for abbreviations.
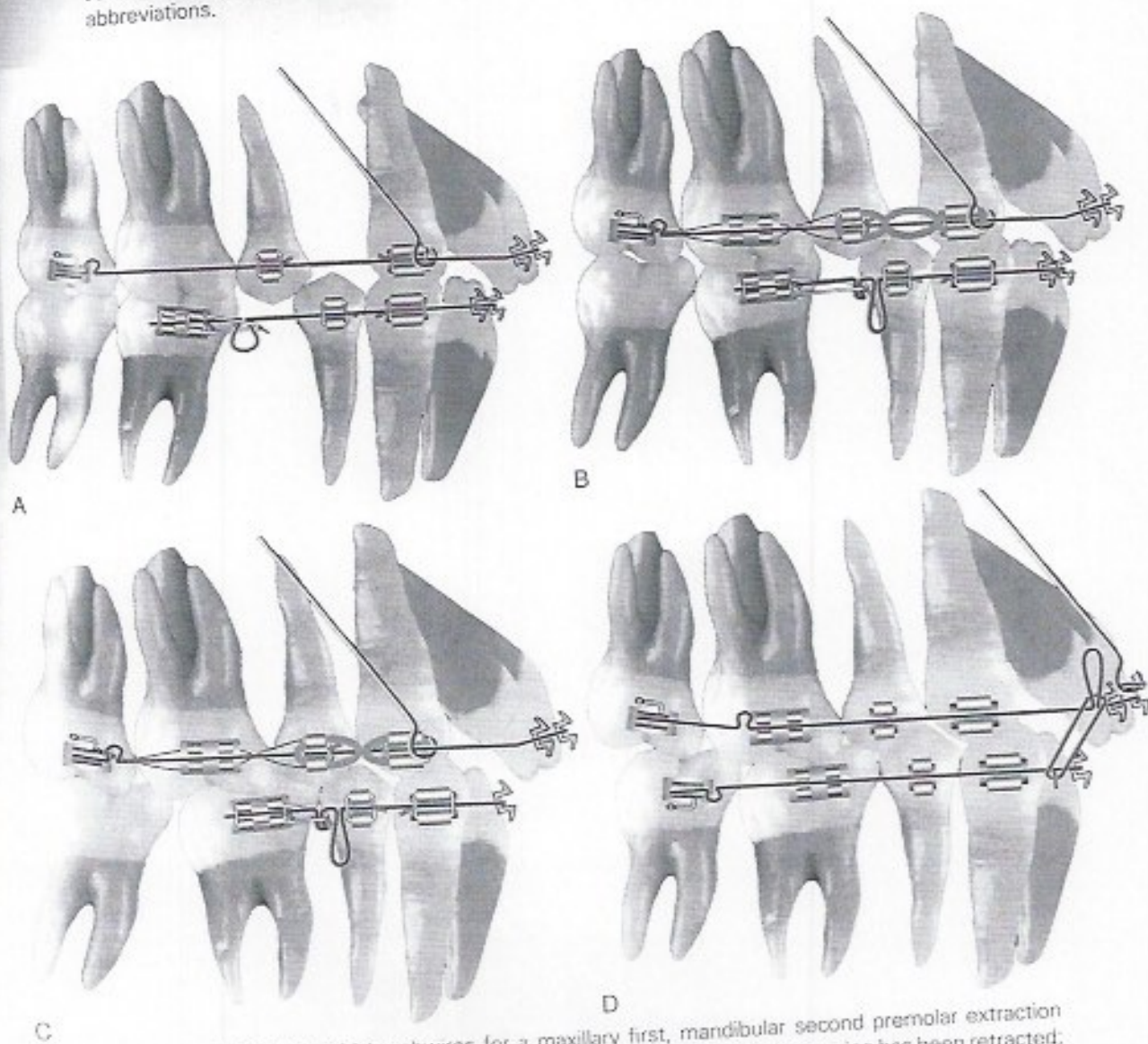

FIGURE 19-53 A, Initial archwires for a maxillary first, mandibular second premolar extraction patient. B, Mandibular first molar protraction archwire. C, The maxillary canine has been retracted; the mandibular first molar has been protracted. D, The mandibular second molar is banded, and mandibular anchorage is prepared.

CASE REPORTS: MALOCCLUSION CORRECTION WITH THE EDGEWISE APPLIANCE—cont'd

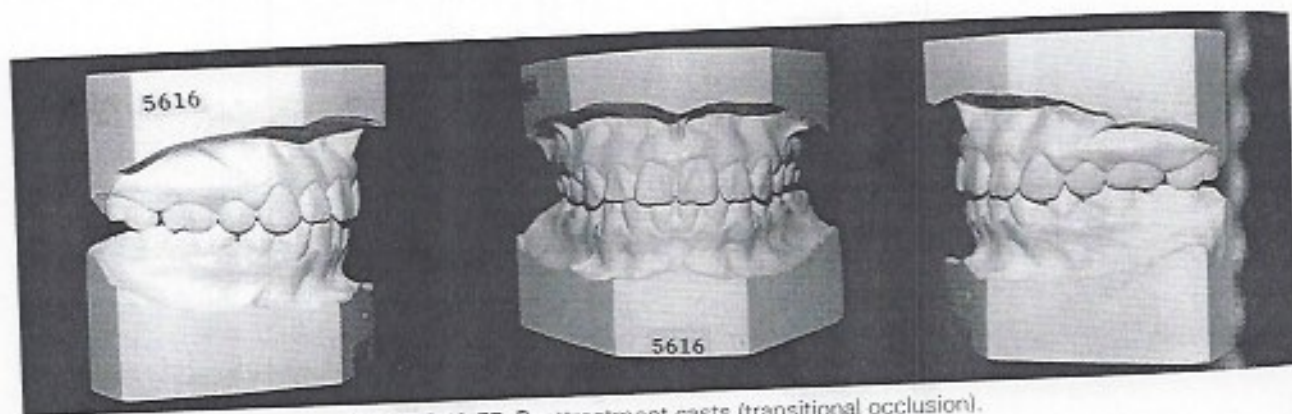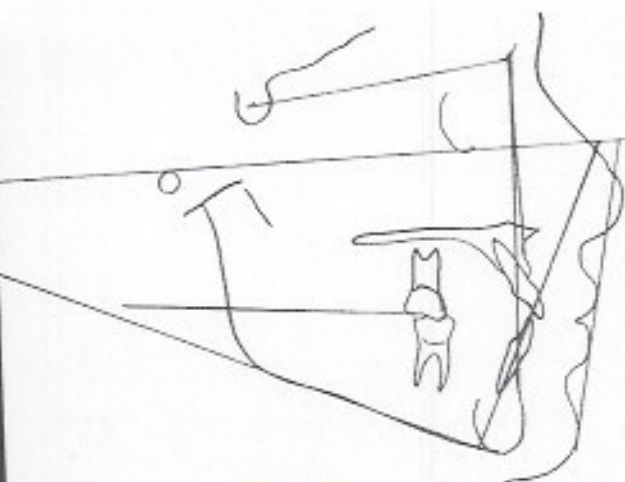FIGURE 19-54 Posttreatment facial photographs.

FIGURE 19-55 Posttreatment casts (transitional occlusion).

FMIA	65
FMA	23
IMPA	92
SNA	86
SNB	83
ANB	3
AO-BO	2 mm
OP	6
Z	78
UL	14 mm
TC	14 mm
PFH	47 mm
AFH	60 mm
FHI	0.77

FIGURE 19-56 Posttreatment cephalogram and tracing. See Figure 19-13 for abbreviations.

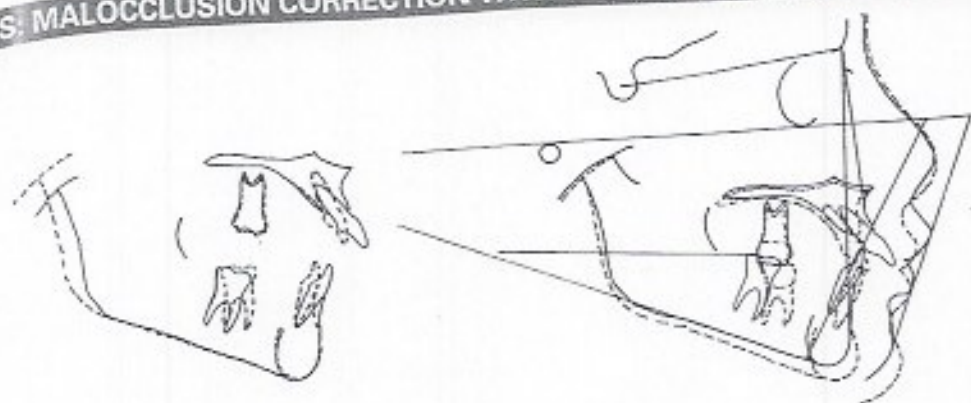# CASE REPORTS: MALOCCLUSION CORRECTION WITH THE EDGEWISE APPLIANCE—cont'd

FIGURE 19-57 Pretreatment–posttreatment superimpositions.

REFERENCES

1. Angle EH. The Treatment of Malocclusion of the Teeth and Fractures of the Maxillae. 6th ed. Philadelphia: SS White; 1900.
2. Angle EH. The Treatment of Malocclusion of the Teeth. 7th ed. Philadelphia: SS White; 1907.
3. Tweed CH. Reports of cases treated with the edgewise arch mechanism. Angle Orthod. 1932;2:236.
4. Tweed CH. The application of the principles of the edgewise arch in the treatment of Class II, Division 1, part I. Angle Orthod. 1936;6(3):198–208.
5. Tweed CH. The application of the principles of the edgewise arch in the treatment of Class II, Division 1, part II. Angle Orthod. 1936;6(4):255–257.
6. Strang RH. Highlights of sixty-four years in orthodontics. Angle Orthod. 1974;44.
7. Tweed CH. A philosophy of orthodontic treatment. Am J Orthod Oral Surg. 1945;31:74.
8. Tweed CH. Indications for the extraction of teeth in orthodontic procedures. Am J Orthod Oral Surg. 1944;30:405.
9. Tweed CH. The Frankfort mandibular incisor angle (FMIA) in orthodontic diagnosis, treatment planning and prognosis. Am J Orthod Oral Surg. 1954;24:121.
10. Tweed CH. Clinical Orthodontics. Vols. 1 and 2. St. Louis: Mosby; 1966.
11. Merrifield LL. The dimensions of the denture: back to basics. Am J Orthod Dentofac Orthop. 1994;106:535.
12. Merrifield LL. The profile line as an aid in critically evaluating facial esthetics. Am J Orthod. 1966;11:804.
13. Merrifield LL. Differential diagnosis with total space analysis. J Charles H Tweed Int Found. 1978;6:10.
14. Merrifield LL. Identification and Classification of Orthodontic and Orthognathic Disharmonies, unpublished lecture. Rio de Janeiro: Brazilian Society of Orthodontics; November 20, 1997.
15. Merrifield LL, Cross JJ. Directional force. Am J Orthod. 1970;57:435.
16. Merrifield LL. The systems of directional force. J Charles H Tweed Int Found. 1982;10:15.
17. Merrifield LL. Differential diagnosis. Semin Orthod. 1996;2:241.
18. Merrifield LL, Klontz HA, Vaden JL. Differential diagnostic analysis systems. Am J Orthod Dentofac Orthop. 1994;106:641.
19. Bishara SE, Hession TJ, Peterson LC. Longitudinal soft tissue profile changes. Am J Orthod. 1985;88:209.
20. Burstone CJ. The integumental contour and extension patterns. Angle Orthod. 1959;29:93.
21. Burstone CJ. Lip posture and its significance in treatment planning. Am J Orthod. 1967;53:262.
22. Johnston L. Nothing personal. Newsletter of the Great Lakes Association of Orthodontists. 1997;33:3.
23. Horn A. Facial height index. Am J Orthod Dentofac Orthop. 1992;102(2):180.
24. Radziminski G. The control of horizontal planes in Class II treatment. J Charles H Tweed Int Found. 1987;15:125.
25. Gebeck TR, Merrifield LL. Orthodontic diagnosis and treatment analysis: concepts and values, part I. Am J Orthod Dentofac Orthop. 1995;107(4):434.
26. Merrifield LL, Gebeck TR. Analysis: concepts and values, part II. J Charles H Tweed Int Found. 1989;17:49.
27. Isaacson RJ. The geometry of facial growth and its effect on the dental occlusion and facial form. J Charles H Tweed Int Found. 1981;9:21.
28. Pearson LE. Vertical control in treatment of patients having backward rotational growth tendencies. Angle Orthod. 1978;43:132.
29. Pearson LE. Vertical control in fully-banded orthodontic treatment. Angle Orthod. 1986;56:205.
30. Schudy FF. Sound biological concepts in orthodontics. Am J Orthod. 1973;63:376.
31. Gebeck TR, Merrifield LL. Analysis: concepts and values, part I. J Charles H Tweed Int Found. 1989;17:19.
32. Merrifield LL, Gebeck TR. Orthodontic diagnosis and treatment analysis: concepts and values, part II. Am J Orthod Dentofac Orthop. 1995;107:541.
33. Gramling JF. A cephalometric appraisal of the results of orthodontic treatment on fifty-five unsuccessfully corrected difficult Class II malocclusions. J Charles H Tweed Int Found. 1987;15:112.
34. Gramling JF. A cephalometric appraisal of the results of orthodontic treatment on one hundred fifty successfully corrected difficult Class II malocclusions. J Charles H Tweed Int Found. 1987;15:102.
35. Gramling JF. The probability index. J Charles H Tweed Int Found. 1989;17:82.
36. Gramling JF. The probability index. Am J Orthod Dentofac Orthop. 1995;107:165.
37. Baldridge D. Leveling the Curve of Spee: Its Effect on Mandibular Arch Length, unpublished master's thesis. Memphis: University of Tennessee; June 1960.
38. Bjork A, Jensen E, Palling M. Mandibular growth and third molar impaction. Eur Orthod Soc Trans. 1956;164.
39. Ledyard BC. A study of the mandibular third molar area. Am J Orthod. 1953;39:366.
40. Richardson ME. Development of the lower third molar from ten to fifteen years. Angle Orthod. 1973;43:191.
41. Andrews LF. The six keys to normal occlusion. Am J Orthod. 1972;62(3):296.
42. Burstone CJ. Application of bioengineering to clinical orthodontics. In: Graber TM, Vanarsdall RL, eds. Orthodontics: Current Principles and Techniques. 2nd ed. St. Louis: Mosby; 1994.
43. Lindqvist JT. The edgewise appliance. In: Graber TM, Vanarsdall RL, eds. Orthodontics: Current Principles and Techniques. 2nd ed. St. Louis: Mosby; 1994.

44. Roth RH. Treatment mechanics for the straight wire appliance. In: Graber TM, Swain B, eds. *Orthodontics: Current Principles and Techniques.* 1st ed. St. Louis: Mosby; 1985.

45. Klontz HA. Tweed-Merrifield sequential directional force treatment. *Semin Orthod.* 1986;2:254.

46. Merrifield LL. Edgewise sequential directional force technology. *J Charles H Tweed Int Found.* 1986;14:22.

47. Vaden JL, Klontz HK, Dale JG. The Tweed Merrifield edgewise appliance. In: Graber TM, Vanarsdall RL, eds. *Orthodontics: Current Principles and Techniques.* 3rd ed. St. Louis: Mosby; 2000.

48. Klontz HA. *Readout. J Charles H Tweed Int Found.* 1985;13:53.