There are essentially five concepts which comprise the modern Tweed-Merrifield Sequential Directional Force treatment philosophy. These concepts are: (1) sequential appliance application, (2) sequential and/or individual tooth movement, (3) sequential mandibular anchorage preparation, (4) directional forces which control the vertical dimension to enhance mandibular response, and (5) proper timing of treatment. Tweed-Merrifield Sequential Edgewise Directional Force Treatment can be organized into four steps: denture preparation, denture correction, denture completion, and denture recovery. During each of these steps, there are certain treatment objectives that must be attained. This article outlines the modern Tweed-Merrifield treatment concept. (Semin Orthod 1996;2:254-267.) Copyright 1996 by W.B. Saunders Company

Using Tweed's treatment concepts as a foundation, L. Lavern Merrifield has developed force systems that simplify the use of the edgewise appliance. Today, with the modern edgewise appliance, only four to five sets of archwires are used. Merrifield Edgewise Sequential Directional Force Technology is a simple, straightforward and fundamentally sound approach to orthodontic mechanotherapy. From the era of Tweed into the era of Merrifield, the key to a quality treatment result with the edgewise appliance continues to be directionally controlled precision archwire manipulation. There are essentially five concepts which comprise the treatment philosophy. These concepts are: (1) sequential appliance application, (2) sequential and/or individual tooth movement, (3) sequential mandibular anchorage preparation, (4) directional forces which control the vertical dimension to enhance mandibular response, and (5) proper timing of treatment.

Sequential Appliance Application

The placement of the appliance on the patient's teeth is important. The second molars, and the second premolars are banded. The canines, centrals, and laterals are bonded. The laterals are generally not ligated for the first 3 to 4 months of treatment. On extraction patients, this procedure allows space to develop from canine retraction before anterior alignment. This method of sequential appliance placement is less traumatic to the patient and is easier for the orthodontist. It gives the archwire much longer interbracket length which creates a power storage that accomplishes treatment objectives more rapidly. After the banded or bonded teeth respond to the forces of the archwires and the auxiliaries, additional posterior teeth are banded, and malaligned bonded anterior teeth are ligated in sequence so that the applied forces can be most efficient.

Sequential Tooth Movement

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

Tweed attempted, with varying degrees of success, to prepare mandibular anchorage with Class III elastics. All the second order compensation bends were placed in the archwire simultaneously. Sequential mandibularanchorage preparation, developed by Merrifield, is the system that allows mandibular anchorage to be prepared quickly and easily by tipping only two teeth at a time to their anchorage prepared position. This system uses the high-pull headgear for support rather than Class III elastics. Unlike the en masse anchorage of the Tweed era, it is controlled. It is referred to as the “10-2 system” because it uses 10 teeth to facilitate the desired movement of two teeth.

Directional Force

A 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 relationships with their environment.

The resultant vector of all forces should be counterclockwise so that the opportunity for a favorable skeletal change is enhanced, particularly for dental-occlusal protrusion and Class II malocclusion corrections. An upward and forward force system requires that the mandibular incisors be upright over basal bone so that the maxillary incisors can be moved distally and superiorly. For the upward and forward force system to be a reality, vertical control is critical. To control the vertical dimension, the clinician must control the mandibular plane, the occlusal plane, and the palatal plane. If Point B drops down and back, the face becomes lengthened, the mandibular incisor is tipped forward off basal bone, and the maxillary incisor drops down and back instead of being moved up and back.

Timing of Treatment

Treatment should be initiated at the time when treatment objectives can be most readily accomplished. This may mean interceptive treatment in the mixed dentition, selected extractions in the mixed dentition, or waiting for second molar eruption before initiating active treatment. Diagnostic discretion is the determinant.

Steps of Treatment

Tweed-Merrifield Sequential Edgewise Directional Force Treatment can be organized into four steps: denture preparation, denture correction, denture completion, and denture recovery. During each step of treatment, there are certain objectives that must be attained.

Denture Preparation

Denture preparation prepares the malocclusion for correction. Objectives include: (1) leveling, (2) individual tooth movement and rotation correction, (3) retraction of both maxillary and mandibular canines, and (4) preparation of the terminal molars for stress resistance. The denture preparation stage of treatment takes approximately 6 months. One mandibular archwire and one maxillary archwire are used to complete this initial step of treatment.

The teeth are sequentially banded and bonded. After the placement of the appliance, an .018 x .025 resilient mandibular archwire and an .017 x .022 resilient maxillary archwire are placed. The loop stops are flush with the second molar tubes (Fig 1). The mandibular second molar receives an effective distal tip of 15° from this initial archwire. In the maxillary arch, there is enough tip in the wire distal to the loop stop to have an effective 5° distal tip on the second molar. The objective in each respective arch is to maintain the maxillary second molar in its already distally tipped position and to begin tipping the mandibular second molar to an anchorage prepared position. High-pull J-hook headgear are used to retract both maxillary and mandibular canines. After each month of treatment, both archwires are removed, more teeth are banded when space develops, and the terminal molar tip in the mandibular archwire is increased to maintain an effective 15° tip as the tooth tips distally. At the end of the denture preparation step of treatment, the mandibular arch should be level, the maxillary and mandibular canines should be retracted, all rotations should be corrected, and the mandibular terminal molars should be tipped distally into an anchorage prepared position of approximately 15° (Fig 2).
Denture Correction

The second step of treatment is called denture correction. During denture correction the anterior teeth are retracted with maxillary and mandibular closing loops which are supported by J-hook headgear attached to hooks soldered between the maxillary and mandibular central and lateral incisors. The mandibular archwire is an .019 × .025 working archwire with 6.5 mm vertical loops distal to the lateral incisor brackets. The .020 × .025 maxillary archwire has 7 mm vertical loops distal to the lateral incisor brackets (Fig 3). The maxillary archwire is coordinated with the mandibular archwire and activated each month until the maxillary incisors are intruded and retracted. With each monthly activation, the mandibular archwire needs to be united and the lingual crown torque in the mandibular anterior segment increased so that the mandibular incisors will be uprighted. At the end of space closure, the curve of occlusion on the maxillary arch should have been maintained, and the mandibular arch should have been completely leveled with the 15° distal tip of the second molar maintained. The dentition is now ready for mandibular anchorage preparation.

Sequential Mandibular Anchorage Preparation

Sequential mandibular anchorage preparation is based on sequential tooth movement. The concept is that the archwire should effect an active force on only two teeth while remaining passive to the other teeth in the arch; thus, the remain-

Figure 1. Denture preparation: An .022 edgewise appliance is sequentially placed. .017 × .022 maxillary and .018 × .025 mandibular archwires are inserted. The high-pull headgears are applied mesial to the canine brackets.

Figure 2. End of denture preparation: The arches are leveled, the rotations are corrected, the canines have been retracted, and the mandibular terminal molar has been tipped to an anchorage-prepared position.

Figure 3. Denture correction: A mandibular .019 × .025 closing loop archwire and a maxillary .020 × .025 closing loop archwire are fabricated. The J-hook headgears are worn in hooks soldered to the anterior segment of both archwires.
ing teeth act as stabilizing or anchorage units as two teeth are tipped. The anchorage bends are supported by a high-pull headgear that is attached to gingival vertical spurs soldered distal to the mandibular central incisors. The amount of headgear wear required is usually 10 to 12 hours per day for first molar anchorage and 8 hours per day for second premolar anchorage.

Sequential mandibular anchorage preparation was initiated during the denture preparation step of treatment by tipping the second molar to a 15° distal inclination. To tip the mandibular first molars to an anchorage prepared position, a 10° distal tip is placed 1 mm mesial to the first molar brackets. A compensating bend that maintains the 15° of terminal molar tip is placed just mesial to the loop stop. The archwire is now passive to the second molar and crosses the twin brackets of the first molar at a 10° bias (Fig 4). The second molars are 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.

Figure 4. First molar anchorage preparation. The .019 × .025 mandibular archwire biases the first molar bracket at a 10° angle. The first molar anchorage is supported by the high-pull headgear applied to the hooks soldered to the mandibular archwire distal to the lateral incisors.

The third and final step of sequential mandibular anchorage preparation is to place a 5° distal tip 1 mm mesial to the second premolar brackets. A compensating bend is placed in the embrasure between the second premolars and the first molars to maintain the first molars in their anchorage prepared position (Fig 5). The archwire must be passive in the brackets of the first molars and in the second molar tubes. The archwire is ligated and again the high-pull J-hook headgear is attached to the vertical spurs. At the end of mandibular anchorage preparation the second molars have a distal axial inclination of 15°, the first molars have a distal axial inclination of 5° to 8°, and the second premolars have a distal axial inclination of 3° to 5°.

The denture correction step of treatment should now be complete for the Class I malocclusion. The objectives of the denture correction step of treatment for the correction of the Class I malocclusion are: (1) complete space closure in both arches, (2) sequential anchorage preparation in the mandibular arch, (3) an enhanced curve of occlusion in the maxillary arch, (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 Class II Force System

For patients who have an "end-on" or a full-step Class II relationship of the buccal segments after mandibular anchorage preparation, a new sequential force system and/or diagnostic decision
Figure 6. Maxillary bulbous loop archwire: An .020 × 025 archwire with a closed helical bulbous loop is inserted. Before insertion, the bulbous loop is opened so a distalizing force is applied to the maxillary second molar. The distalizing force is supported with Class II elastics, anterior vertical elastics, and a high-pull headgear.

Figure 8. Maxillary closing loop archwire for anterior space closure after Class II correction. An .020 × .025 closing loop archwire is fabricated to close residual maxillary space. Class II elastics, anterior vertical elastics, and the high-pull headgear are used.

Figure 7. Maxillary bulbous loop archwire with a first molar jig: An .030 jig is placed mesial to the maxillary first molar. The forces are generated by a Class II elastic to the jig, a Class II elastic to the hook on the maxillary archwire, anterior vertical elastics, and the high-pull headgear.

Figure 9. Decatur completion archwires: Maxillary and mandibular .0215 × .0275 archwires are fabricated. Hooks are soldered distal to the canines for the use of Class II elastics and anterior vertical elastics. The force system used depends on final tooth positions that need to be achieved.
must be used to complete denture correction. It is absolutely necessary to make a final diagnostic decision for Class II correction based on (1) the ANB relationship, (2) the FMA, (3) a maxillary posterior space analysis, and (4) patient cooperation. The following guidelines are used:

1. If the maxillary third molars are missing, if the ANB is 5° or less, if the vertical dimension is within reasonable limits, and if 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 denture.

2. If the ANB relationship is 5° to 8°, if the FMA is moderate and if a Class II cusp relationship exists, the extraction of the maxillary second molars will be the most advantageous extraction choice for the cooperative patient. The force system to be described is used to distalize the maxillary arch into the second molar extraction space.

3. If the ANB is above 10° and the FMA is high, and/or if the patient’s motivation is question-
able, either the first molars should be removed, or surgical correction should be considered. Desired and projected facial balance after correction should also be carefully considered before making either decision.

The Class II force system cannot be used unless patient compliance is assured. If an attempt is made to use the Class II force system without patient cooperation, the maxillary anterior teeth will be pushed forward.

At the end of sequential mandibular anchorage preparation, an ideal mandibular .0215 × .028 stabilizing archwire is fabricated. Gingival spurs are soldered on the wire distal to the mandibular lateral incisors. An .020 × .025 maxillary archwire with closed helical bulbous loops bent flush against the second molar tubes is fabricated. There is 7° of progressive lingual crown torque in the molar segment. Gingival high-pull headgear hooks are soldered distal to the central incisors. Class II hooks are soldered to the archwire mesial to the canines. The helical bulbous loops are opened 1 mm on each side, and the archwire is ligated. Eight ounce Class II elastics are worn from the hooks on the mandibular second molar tubes to the Class II hooks on the maxillary archwire. The Class II elastic force and the activation of the closed helical bulbous loops generate a distalizing force on the maxillary second molars. To maintain the position of the mandibular incisors, anterior vertical elastics are worn from the spurs on the mandibular archwire to the high-pull headgear hooks on the maxillary archwire. The high-pull headgear is also worn on these same maxillary hooks (Fig. 6). This force system is used for approximately 1 month to sequentially move the maxillary second molars distally. After maxillary second molar distalization, sliding .030 jigs are fabricated and placed on the maxillary archwire so that the distal clefts contact the mesial bracket of the maxillary first molars and the mesial clefts are

Figure 12. Pretreatment facial photographs of NG. The facial photographs reveal lip imbalance, mandible strain, and confirm the bimaxillary dental protrusion.

Figure 13. Pretreatment casts of NG. The Class II occlusion with deep overbite and overjet is noted.
midway between the canine and premolar brackets. The mental eyelet has an extension for a Class II elastic (Fig 7). At this time, 6 oz Class II elastics are worn 24 hours each day from the hook on the mandibular second molar tube to the sliding jig, and a second set to 8 oz Class II elastic is worn from the mandibular second molar hook on the Class II hook on the maxillary archwire. An anterior vertical elastic is worn 12 hours each day. The high-pull headgear is attached to the maxillary archwire 14 hours per day. This directional force system is sequential because the maxillary second molars, the maxillary first molars, and the rest of the maxillary teeth receive individual distal force to position the posterior teeth in an overcorrected Class I relationship.

After overcorrection of the Class II relationship of the posterior teeth, it may be necessary to fabricate an .020 × 0.025 maxillary archwire with 7 mm closing loops bent distal to the lateral incisors (Fig 8). The closing loops are opened 1 mm per visit by cinching the loop stops to the molar tube. The Class II force is 4 to 6 oz. The anterior vertical elastics and the maxillary high-pull headgear are used in conjunction with these light Class II elastics. When all the maxillary space is closed, the patient is ready for the next step of treatment, ie, denture completion.

Denture Completion

Ideal mandibular and maxillary .0215 × .028 resilient archwires are fabricated. Hooks for the high-pull headgear, for anterior vertical elastics, and for Class II elastics are soldered to the archwires as previously described. Supplemental hooks for vertical elastics are soldered as needed (Fig 9). The forces used during denture completion are based on a study of the arrangement of each tooth in each arch. The relationship of one arch to the other, and the relationship of the arches to their entire environment is also studied. Necessary adjustments are made in each archwire as needed. Denture completion can be considered as mini-treatment of the malocclusion. During this treatment step, the orthodontist repeats the systems of forces that are necessary until the original malocclusion is overcorrected. After overcorrection, the final artistic bends and cusp seating forces that give detail and quality to the overcorrected malocclusion are added.

Figure 14. Pretreatment panoramic radiograph of NG. The radiograph illustrates a healthy dentition with developing third molars.

Figure 15. (A) Pretreatment cephalometric radiograph of NG. The radiograph confirms the retrusive mandibular position and the bialveolar dental protrusion. (B) Pretreatment tracing of NG. The pretreatment tracing exhibits a maxillary and mandibular bialveolar protrusion, facial imbalance, and the skeletal imbalance. FMIA 41°, SMA 34°, IMPA 103°, SNA 85°, SBN 73°, ANB 10°, AO/BO 9 mm, OGC 15°, Z 48°, UI 10 mm, TC 9 mm, PEF 42 mm, AFH 63 mm, Index 58.
### Differential Diagnostic Analysis System

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#### Cranial Facial Analysis

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**Figure 16.** Differential diagnostic analysis worksheet of NG. The total dentition difficulty of 215.5 confirms the severe difficult malocclusion condition.

### Denture Recovery

The orthodontist should not strive for the ideal final result at the end of treatment. The ideal result will occur 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, the most critical “recovery” phase occurs. The latter is the recovery period, and 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, there will be inevitable relapse. Any change

**Figure 17.** Posttreatment facial photographs of NG. Posttreatment photographs reflect a balanced and pleasing facial profile.
is likely to be away from ideal occlusion toward malocclusion. Recovery, based on a concept of overcorrection is predicated on clinical experience and research. Certain tooth and denture changes effected during treatment will tend to revert toward their original position.

Orthodontists not familiar with the concept of overtreatment have expressed some concern about the posterior occlusion that is achieved at the completion of treatment. This treatment occlusion (Fig 10), sometimes referred to as "Tweed occlusion," but properly identified as transitional occlusion, is characterized by a disclusion of the second molars and the distal cusps of the first molars. The mesial lingual 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. The maxillary second premolar buccal cusp contacts the distal inclined plane of the mandibular second premolar buccal cusp, while the distal inclined plane of the maxillary second premolar buccal cusp contacts the mesial inclined plane of the mesial buccal 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 can now re-erupt 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 rapidly adjust to an ideal overjet and overbite relationship. The muscles of swallowing, expression, and mastication are actively involved in determining the final stable, esthetic relationship of the teeth, referred to as functional occlusion (Fig 1).

This concept of a transitional occlusion followed by a period of recovery is based on the belief that each individual's own oral environment will determine the ultimate position of the dentition and that overtreatment allows the patient the greatest opportunity for maximum stability and functional efficiency. Orthodontists who subscribe to this concept of overtreatment should display patient records made both at the

Figure 18. Posttreatment casts of NG. The posttreatment casts reflect correction of the Angle's Class II, Division 1 malocclusion into an occlusion characterized by canine protection and mesial guidance. Note the molars that have been tipped to an anchorage-prepared position.

Figure 19. Posttreatment panoramic radiograph of NG. The teeth are healthy, as the teeth adjacent to the extraction sites have been adequately uprighted into these sites.
corrected with the Tweed-Merrifield Sequential Directional Force System.

The facial photographs (Fig 12) show poor facial balance on frontal and profile view. The face is characterized by lip protrusion, mentalis strain, and excessive lower anterior facial height.

The casts (Fig 13) illustrate the Angle Class II, Division 1 malocclusion which is characterized by bialveolar protrusion, a deep anterior over-

end of active treatment and 6 months later at the end of recovery.

**Case Report: Angle Class II, Division 1 Malocclusion**

To illustrate the force systems just described, the pretreatment, posttreatment, and recall records of N.G. follow. N.G. presented with a severe Angle Class II, Division 1 malocclusion which was...
bite, and a poor occlusal relationship of the posterior teeth. Note the "peg" maxillary lateral incisors. The panoramic radiograph (Fig 14) illustrates a healthy dentition with normal periodontal support for all the teeth. No third molars are present. The cephalogram (Fig 15A) and its tracing (Fig 15B) confirm the severe skeletal and dental problem. The FMA of $34^\circ$ and the occlusal plane of $15^\circ$ confirm the vertical skeletal and dental problem. The SNB of $73^\circ$ and the ANB of $10^\circ$ confirm the horizontal skeletal problem. The Z-angle of 48 quantifies the facial imbalance.

**Diagnosis**

The Differential Diagnostic Analysis System was used (Fig 16). N.G.'s cranial facial difficulty was 183. This value reflected the severity of the skeletal and facial imbalance. The space analysis difficulty value was 30.5, confirmation of the amount of space that it would take to effect malocclusion correction. The total difficulty for the malocclusion was 218.5. This value was well into the severe category. After a careful consideration of the facial, skeletal, and dental components of the malocclusion, the maxillary and mandibular right and left first premolars were extracted. It appeared that all four third molars were congenitally missing.

**Results**

The posttreatment facial photographs (Fig 17) show marked improvement in facial balance and harmony. Note the reduction of the lip protrusion. The casts (Fig 18) confirm correction of the Class II occlusal relationship to a canine-protected Class I occlusion. Note the preservation of arch form and the correction of the overbite and overjet. The posttreatment panoramic radiograph (Fig 19) illustrates a healthy dentition and the development of a maxillary left third molar. The posttreatment cephalogram (Fig 20A) and its tracing (Fig 20B) confirm the

**Figure 23.** Recall casts of NG. The teeth that were tipped out of occlusion have settled into a functional occlusion characterized with no balancing or working prematurities.
mandibular incisor uprighting, the posterior vertical control and the intrusion and retraction of the maxillary anterior teeth.

The 5-year recall photographs (Fig 22) exhibit continued improvement in facial balance and harmony. The 5-year recall casts (Fig 23) confirm settling of the dentition into a functional occlusal interdigitation. The peg lateral incisors have been restored. The recall cephalogram (Fig 24A) and its tracing (Fig 24B) confirm the stability of the occlusal correction and continued mandibular response. The maxillary left third molar was scheduled for extraction. The pretreatment/posttreatment/recall superimposition (Fig 25) exhibits the further settling of the treatment result into a more ideal relationship.

The force systems that were used to effect the correction of this severe Angle Class II, Division 1 malocclusion were described previously. Sequential Class II correction was initiated after mandibular anchorage had been prepared and stabilized. Class II elastics were supported with anterior vertical elastics and the maxillary high-pull j-hook headgear. This technology enables the clinician to routinely correct many different types of malocclusions with predictability and precision.

Figure 24. (A) Recall cephalometric radiograph of NG. The recall radiograph reflects settling of the teeth into positions that are in balance and harmony with their environment. (B) The recall tracing confirms flattening of the horizontal planes with mandibular response. FMA 60°, FMA 31°, IMPA 89°, SNA 78°, SNB 73°, ANB 3°, AO/BO 3 mm, OGC 14°, L 67°, UE 14 mm, TC 14 mm, PFH 18 mm, ANFH 66 mm, Index 71.

improvement in the tooth position which affected the facial and dental result. The mandibular incisors were uprighted from 105° to 89°. FMA was reduced to 31°, ANB was reduced to 3°. The occlusal plane was controlled. Posterior facial height increased 6 mm while anterior facial height increased only 3 mm. All these measurements confirm good directional force control during malocclusion correction. The pretreatment/posttreatment superimpositions (Fig 21) reflect the downward and forward mandibular response. Note the improvement in the chin to upper lip relationship as well as the

Figure 25. Pretreatment, posttreatment, recall superimpositions of NG. The superimpositions reflect continued mandibular response and continued facial improvement because of this mandibular response. — Pretreatment, --- posttreatment, --- --- 5-year recall.
Acknowledgment

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References