# MBT™ Versatile+ Appliance System

– Appliance Torque and Tip
– Arch Forms
– Bracket Placement Guide

# Efficient Treatment Solutions for Clinical Excellence

MBT™
Versatile+ Appliance System

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# MBT™

## Versatile+ Appliance System

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# The MBT™ Versatile+ Appliance System

For more than 100 years, the science of orthodontics has evolved continuously, incorporating new technologies and philosophies as more was learned about tooth movement, and as the need for greater efficiency increased. One of the most significant routes of evolution has been the role of brackets and buccal tubes: originally they were simply holders of bent archwire, but as torques and tips were built into them, a new approach to orthodontic treatment developed. Today, the evolution continues, as practitioners continue to incorporate the concept of pre-adjusted appliances with the constant objective of continuous, effective tooth movement.

Dr. Lawrence F. Andrews developed the first programmed pre-adjusted appliance system in the late 1960s. The values built into the appliance system were based on his study of 120 non-orthodontic normal study models[1]. After using the basic Straight-Wire® Appliance for some time, Andrews determined that special auxiliary appliances were required in specific orthodontic situations. He employed anti-tip, anti-rotation and power arms in the posterior segments of extraction cases to better control space closure. He also advocated some variability in the torque values on certain teeth, using three sets of incisor brackets with different levels of torque for different clinical treatment needs.[2]

Dr. Ron Roth[3] included the element of inventory management into the pre-adjusted appliance system by developing a single set of bracket values to be used on all cases, extraction and non-extraction. The torque and tip values in his system, as is the case with Dr. Andrews, were based in part on the treatment mechanics they were employing in their practice at the time.

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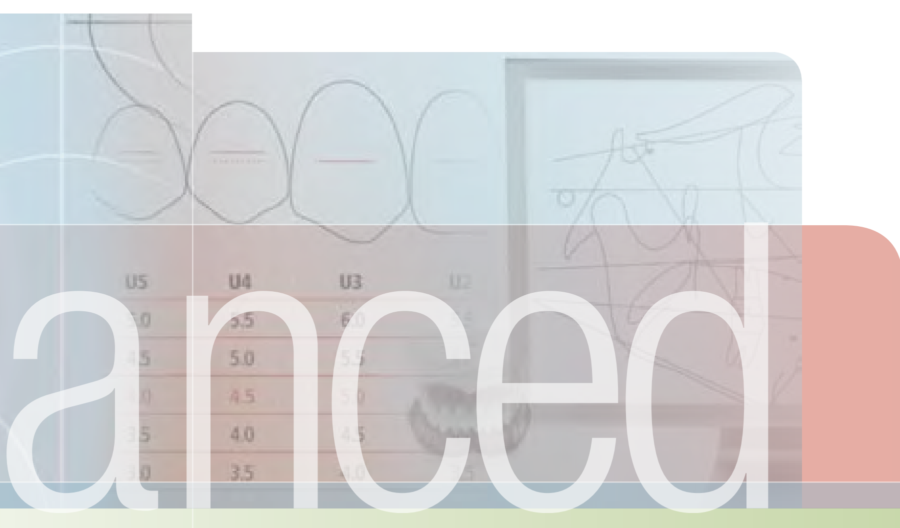
Drs. Richard McLaughlin, John Bennett and Hugo Trevisi, in the early 1990s, found that with the application of light continuous forces, instead of the traditional approach of applying edgewise forces to pre-adjusted appliances, the brackets did not need the additional compensations built into previous systems. They referred directly to the data that influenced the first Straight-Wire Appliance.

After refining the mechanics of their system for approximately six years, they collaborated with 3M Unitek to manufacture products that supported their treatment approach. Further collaboration developed certain aspects of the system, including an increase in palatal root torque in the lower anteriors, reduced lingual crown torque in lower second molars, and a modification in the tip in upper molars. After further testing to ensure the system provided the desired orthodontic results, the MBT™ Versatile+ Appliance System was launched by 3M Unitek in 1997.[7]

Since then, the MBT Appliance System has been adopted by clinicians around the world. There are many challenges that arise during orthodontic treatment, and the MBT Appliance System has leveraged decades of scientific research and clinical experience to deliver a system of efficient, effective solutions to those challenges.

This handbook is an overview of the principal elements of the MBT Versatile+ Appliance System: the appliances, the arch forms, and accurate bracket placement.



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# Incisor Torque

## Treatment Challenge: Torque Loss in Upper Anterior Teeth, Flaring of Lower Anterior Teeth

**The MBT™ Versatile+ Appliance System Solution:**
Torque movement is an extremely difficult aspect of orthodontic treatment, one that requires significant movement through bone with less than 1 mm of contact between the archwire and the bracket to do so. The result of this lack of torque control in many orthodontic cases is a loss of torque in upper incisors during overjet reduction and space closure. In the same way, in many cases the lower incisors tend to procline forward during Curve of Spee leveling and when treating for lower incisor crowding. To counteract these tendencies, greater palatal root torque in the upper incisor area and greater labial root torque in the lower incisor area is needed. In this regard, the MBT Appliance System offers two levels of increased torque for the upper central incisors, depending on the clinical need: +17° or +22°, +10° of torque is offered for the upper lateral incisors, and -6° of torque for the lower incisors.

Table 1 shows torque values from the Andrews' non-orthodontic normal study, two Japanese studies, the original Straight-Wire® Appliance, and the torque values of the MBT Versatile+ Appliance System.

| Table 1 | Incisor | | Torque | |
|---|---|---|---|---|
| | Upper Central | Upper Lateral | Lower Central | Lower Lateral |
| Andrews' Norms[3] | 6.11° | 4.42° | -1.71° | -3.24° |
| Sebata's Data[4] | 9.42° | 7.48° | 3.55° | 1.66° |
| Watanabe's Data[5] | 12.8° | 10.4° | 0.71° | 0.53° |
| Original SWA[3] | 7.0° | 3.0° | -1.0° | -1.0° |
| MBT™ Versatile+ Appliance System | 17.0° | 10.0° | -6.0° | -6.0° |
| MBT Versatile+ Appliance System | 22.0° | 10.0° | -6.0° | -6.0° |

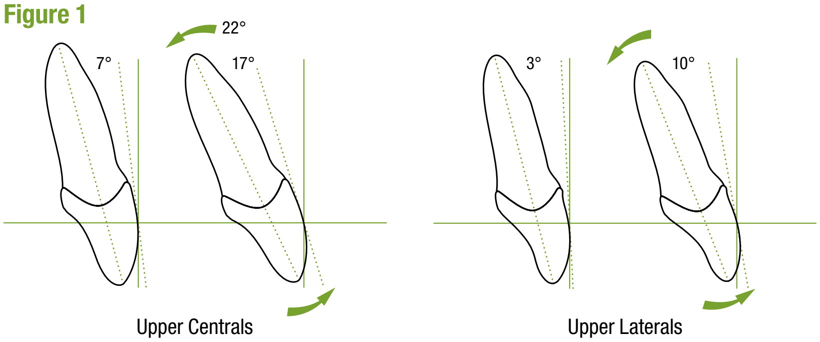
**Table 1:** Measurements for incisor torque from the Andrews' non-orthodontic normal study,[3] two Japanese studies,[4,5] the original Straight-Wire® Appliance[3] and the MBT™ Versatile+ Appliance System.

# Incisor Tip

## Treatment Challenge: Excessive Tip in the Anterior Teeth

**The MBT Versatile+ Appliance System Solution:**
The actual anterior tip measurements for the original Straight-Wire Appliance are all greater than the tip values reported in Andrews' research. It is presumed this was done to control the effect that torque places on anterior crown tip, referred to by Andrews as the "wagon wheel" effect. This is akin to the use of the compensating anti-tip, antirotation and power arms built into the extraction brackets used in treatment that includes bicuspid extraction.

**Figure 1**



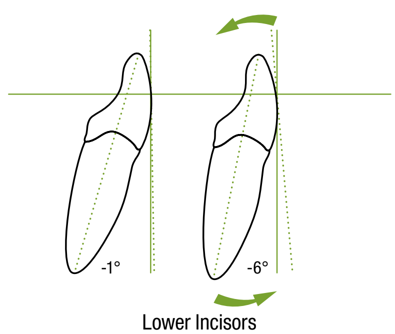




**Figure 1:** To counteract natural tendencies in orthodontic tooth movement, the MBT™ Versatile+ Appliance System offers increased palatal root torque for the upper incisors and increased root torque for the lower incisors.

| Table 2 | Incisor Tip | | | | Cuspid Tip | |
|---|---|---|---|---|---|---|
| | Upper Central | Upper Lateral | Lower Central | Lower Lateral | Upper | Lower |
| Andrews' Norms[3] | 3.59° | 8.04° | 0.53° | 0.38° | 8.4° | 2.5° |
| Sebata's Data[4] | 4.25° | 7.74° | -0.48° | -1.2° | 7.7° | 1.5° |
| Watanabe's Data[5] | 3.11° | 3.99° | 1.98° | 2.28° | 7.7° | 5.4° |
| Original SWA[3] | 5.0° | 9.0° | 2.0° | 2.0° | 11.0° | 5.0° |
| MBT™ Versatile+ Appliance System | 4.0° | 8.0° | 0° | 0° | 8.0° | 3.0° |

**Table 2:** Anterior tip measurements from the Andrews non-orthodontic normal study,[3] from two Japanese studies,[4,5] from the original Straight-Wire® Appliance[3] and the MBT™ Versatile+ Appliance System.

**Figure 2**

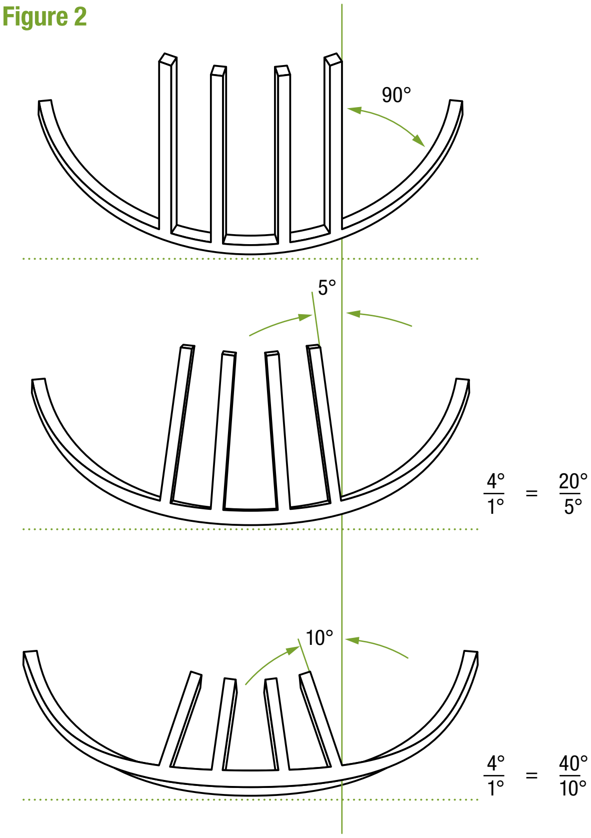



**Figure 2:** Andrews' "wagon wheel" effect.[3] Mesial crown tip decreases as palatal root torque is increased in the anterior segment.

The MBT™ Appliance System employs light continuous force mechanics, and thus tip is well controlled by the pre-adjusted appliance without any additional compensation. The use of lacebacks during leveling and aligning and elastic module tie-backs during space closure substantially reduces adverse tipping in these stages of treatment, so there is no need for increased tip values. By the finishing stage of treatment, full expression of crown tip in both the anterior and posterior teeth are indicated by the finishing rectangular wires, completely leveled in the upper and lower arch.

Table 2 shows the anterior tip measurements from the Andrews non-orthodontic normal study, from two Japanese studies, from the original Straight-Wire® Appliance, and in the MBT Versatile+ Appliance System.

**Figure 3**

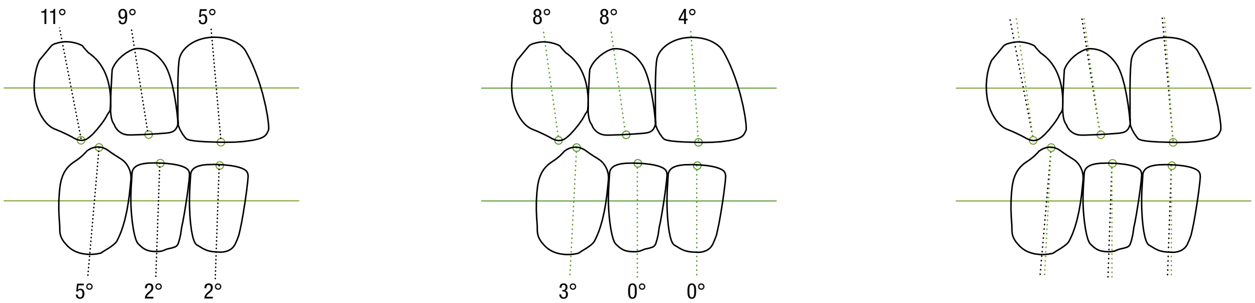



**Figure 3:** The anterior tip values of the MBT™ Versatile+ Appliance System correspond well to Andrews' original norms. The reduced tip acknowledges a reduction in required anchorage when employing low-force mechanics.

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# Upper Posterior Torque

## Treatment Challenge: Palatal Cusp Interference

**The MBT™ Versatile+ Appliance System Solution:**
The difficulty in expressing torque with the pre-adjusted appliance is especially evident in cuspids, the teeth with the longest roots in the human dentition.[8] The MBT Appliance System offers three options in upper cuspid torque in order to best meet the needs of the individual patient. A -7° torque and a 0° torque bracket is available. As a component to the versatility of the system, the -7° torque bracket can be turned upside down when needed to provide a +7° torque option.

The upper first and second bicuspid torque values of -7° are satisfactory in most cases.

One indication of excessive buccal crown torque in the upper molars is the common occurrence of "hanging" palatal cusps, creating centric interferences and requiring further correction (Fig. 4). An increased value of buccal root torque in the MBT Versatile+ Appliance System of -14° in the upper first and second molars, as opposed to -9° of buccal root torque, is offered to better balance the forces on the molars.

Table 3 shows upper cuspid, bicuspid and molar torque values from the Andrews' non-orthodontic normal study, two Japanese studies, and the original Straight-Wire® Appliance.

# Upper Posterior Tip

## Treatment Challenge: Inter-Cuspation Interference

**The MBT Versatile+ Appliance System Solution:**
The MBT Versatile+ Appliance System offers 0° of tip, as opposed to 2° of tip, for all upper bicuspid brackets. The 0° angulation aligns the crowns of these teeth in a more upright position, which is more in the direction of Class I. It also acknowledges, as in the anterior region, less tip required and lower anchorage values needed to perform low-force treatment mechanics.

**Figure 4**

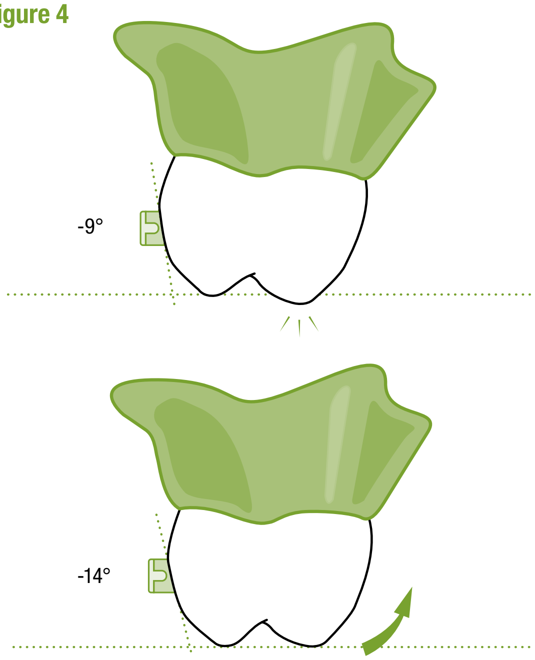


**Figure 4:** The MBT™ Versatile+ Appliance System increases the buccal root torque of the upper molars, reducing the possibility of palatal cusp interferences.

| Table 3 | Upper Cuspid, Bicuspid and Molar Torque | | | | |
|---|---|---|---|---|---|
| | Cuspid | 1st Bicuspid | 2nd Bicuspid | 1st Molar | 2nd Molar |
| Andrews' Norms[3] | -7.3° | -8.5° | -8.9° | -11.5° | -8.1° |
| Sebata's Data[4] | 0.7° | -6.5° | -6.5° | -1.7° | -3.0° |
| Watanabe's Data[5] | -5.3° | -6.0° | -7.2° | -9.8° | -9.5° |
| Original SWA[3] | -7.0° | -7.0° | -7.0° | -9.0° | -9.0° |
| MBT™ Versatile+ Appliance System | -7.0° | -7.0° | -7.0° | -14.0° | -14.0° |
| MBT Versatile+ Appliance System | 0° | -7.0° | -7.0° | -14.0° | -14.0° |
| MBT Versatile+ Appliance System | 7.0° | -7.0° | -7.0° | -14.0° | -14.0° |

**Table 3:** Measurements for cuspid, bicuspid and molar torque from the Andrews' non-orthodontic normal study,[3] two Japanese studies,[4,5] the original Straight-Wire® Appliance[3] and the MBT™ Versatile+ Appliance System.


**Figure 5**

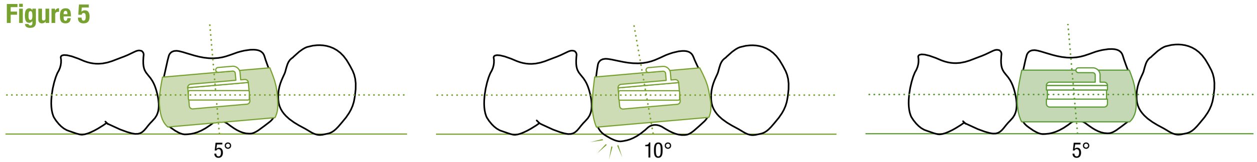


**Figure 5A:** When using a 5° tube, the band must be seated more gingivally at the mesial.

**Figure 5B:** When using a 5° tube, if the band is placed parallel to the buccal cusps, it will effectively deliver a 10° tip to the first molar.

**Figure 5C:** Thus a 0° tip tube, seated parallel to the buccal cusps, delivers the ideal 5° of tip.

The buccal groove in the upper molars is the reference for molar crown tip. This buccal groove shows a 5° angle in reference to a line drawn perpendicular to the occlusal plane. To achieve the desired 5° tip value in the upper first and second molars, there are two approaches: use a 5° buccal tube or use a 0° bracket with a different positioning reference for the band. In the first option, if a 5° tube is used with the bands seated more gingivally at the mesial aspect (Fig. 5A), it is more difficult to actually position the band because it is usually necessary to seat the band up on the mesial surface and frequently trim band material from the distal marginal ridge. This 5° tube, when placed in this way parallel to the occlusal plane, actually provides 10° of tip to the upper first and second molars, which is more than needed (Fig. 5B). In the second option, a 0° tip in the buccal tube slot with the band and the tube slot placed parallel to the occlusal plane provides the ideal 5° of tip in the upper first and second molars as measured from the buccal groove (Fig. 5C).

| Table 4 | Bicuspid Tip | | Molar Tip | |
|---|---|---|---|---|
| | Upper First | Upper Second | Upper First | Upper Second |
| Andrews' Norms[3] | 2.7° | 2.8° | 5.7° | 0.4° |
| Sebata's Data[4] | 3.5° | 6.2° | 5.2° | -0.3° |
| Watanabe's Data[5] | 4.7° | 5.2° | 4.9° | 4.1° |
| Original SWA[3] | 2.0° | 2.0° | 5.0° | 5.0° |
| MBT™ Versatile+ Appliance System | 0° | 0° | 0° | 0° |

**Table 4:** Measurements for the upper bicuspids and upper molars from the Andrews' non-orthodontic normal study,[3] two Japanese studies,[4,5] the original Straight-Wire® Appliance[3] and the MBT™ Versatile+ Appliance System.

Table 4 shows tip measurements for the upper bicuspids and molars from the Andrews' non-orthodontic normal study, two Japanese studies, the original Straight-Wire® Appliance, and the MBT™ Versatile+ Appliance System.

# Lower Posterior Torque

## Treatment Challenge: Lingual Rolling of the Lower Posterior Teeth

**The MBT Versatile+ Appliance System Solution:**

Lingual crown torque is reduced in the lower cuspid, bicuspid and molar areas for three reasons: 1) Gingival recession occasionally presents in lower cuspids, and bicuspids often show gingival recession. In those cases the teeth benefit from roots being moved closer to the center of the alveolar process; 2) Frequently, orthodontic cases show narrowing in the maxillary arch with lower posterior segments that are inclined lingually. In these cases, buccal uprighting is a favorable treatment step in the lower posterior segment.
3) Lower second molars often tend to torque lingually,

particularly when the lower second molars have buccal tubes with -35° or more of torque. For these reasons, the MBT™ Versatile+ Appliance System significantly reduces the lingual crown torque on lower cuspids, bicuspids and molars, as shown in the table below.

Table 5 shows torque values for lower cuspids, bicuspids and molars from the Andrews' non-orthodontic normal study, two Japanese studies, the original Straight-Wire® Appliance, and the MBT Versatile+ Appliance System.

**Figure 6**

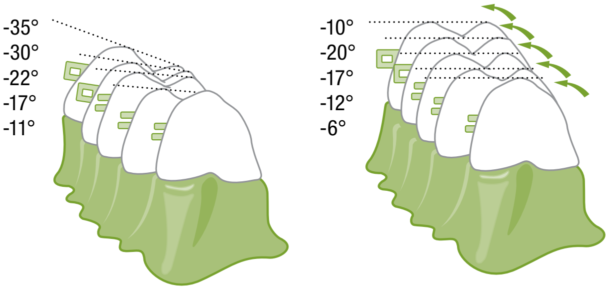


**Figure 6:** Excessive torque in the posterior segments influences the teeth to roll lingually. The MBT™ Versatile+ Appliance System provides reduced torque values in this area, allowing uprighting of the teeth.

# Lower Posterior Tip

## Treatment Challenge: Achieving a Class I Relationship Efficiently

**The MBT Versatile+ Appliance System Solution:**

The original Straight-Wire Appliance 2° of mesial crown tip in the lower bicuspids is reflected in the MBT Versatile+ Appliance System. This angulation effectively orients the bicuspids more in a Class I manner. A 0° tip in the lower molars achieves the objective of a 2° tip much in the same way tip is achieved in the upper first molars. The lower buccal groove is 2° off of a line drawn perpendicular to the occlusal plane. Introducing this 2° of tip to the lower molars, then, can be accomplished by placing a 0° tip buccal tube parallel to the occlusal plane. Therefore, the lower bicuspid brackets show 2° of mesial crown tip and the lower molar buccal tubes show 0° of crown tip with the bands placed parallel to the occlusal surface.

Table 6 shows tip values for lower bicuspids and molars from the Andrews' non-orthodontic normal study, two Japanese studies, the original Straight-Wire Appliance, and the MBT Versatile+ Appliance System.

| Table 5 | Lower Cuspid, Bicuspid and Molar Torque | | | | |
|---|---|---|---|---|---|
| | Cuspid | 1st Bicuspid | 2nd Bicuspid | 1st Molar | 2nd Molar |
| Andrews' Norms[3] | -12.7° | -19.0° | -23.6° | -30.7° | -36.0° |
| Sebata's Data[4] | -4.7° | -14.8° | -22.6° | -26.2° | -31.0° |
| Watanabe's Data[5] | -11.1° | -18.4° | -21.8° | -31.2° | -32.9° |
| Original SWA[3] | -11.0° | -17.0° | -22.0° | -30.0° | -35.0° |
| MBT™ Versatile+ Appliance System | -6.0° | -12.0° | -17.0° | -20.0° | -10.0° |

**Table 5:** Measurements for lower cuspid, bicuspid and molar torque from the Andrews' non-orthodontic normal study,[3] two Japanese studies,[4,5] the original Straight-Wire® Appliance[3] and the MBT™ Versatile+ Appliance System.

| Table 6 | Lower Bicuspid Tip | | Lower Molar Tip | |
|---|---|---|---|---|
| | Lower First | Lower Second | Lower First | Lower Second |
| Andrews' Norms[3] | 1.3° | 1.54° | 2.0° | 2.9° |
| Sebata's Data[4] | 2.5° | 6.70° | 5.7° | 7.3° |
| Watanabe's Data[5] | 3.8° | 3.91° | 3.7° | 3.9° |
| Original SWA[3] | 2.0° | 2.0° | 2.0° | 2.0° |
| MBT™ Versatile+ Appliance System | 2.0° | 2.0° | 0° | 0° |

**Table 6:** Measurements for the lower bicuspids and lower molars from the Andrews' non-orthodontic normal study[3] two Japanese studies,[4,5] the original Straight-Wire® Appliance[3] and the MBT™ Versatile+ Appliance System.

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# Second Bicuspid Tooth Options

## Two In-Out Options

Even in systems where there are multiple tip or torque options for an individual tooth, traditional straight-wire appliances have offered only one in-out measurement. These in-out values have, after decades of clinical use, shown to be adequate to achieve proper alignment, requiring special wire bends only in exceptional cases. The MBT™ Versatile+ Appliance System does, however, offer two in-out options for the upper second bicuspid.

Upper first and second bicuspids can vary in relative size to each other, where the second bicuspid is frequently smaller. When the upper first and second bicuspids are generally equal in size, an upper first bicuspid bracket may be used on both teeth. In cases where the upper second bicuspid is smaller, the system offers an upper second bicuspid bracket with an additional 0.5" thickness in in-out compensation. This allows for better alignment of central fossae in the upper arch and will also provide for increased mesio-buccal rotation of the upper first molar (Fig. 7).

**Figure 7**

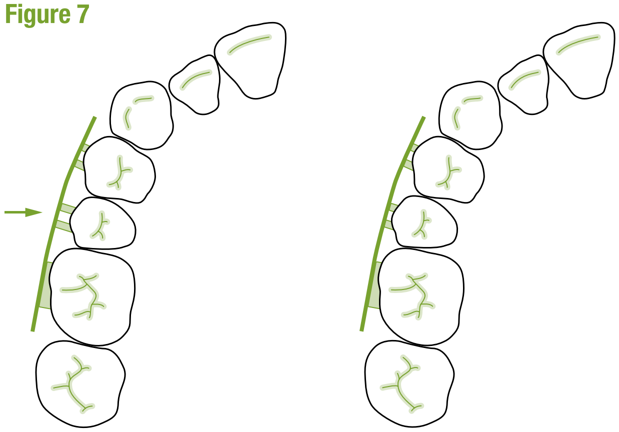


**Figure 7:** The MBT™ Versatile+ Appliance System offers the option of a bicuspid bracket that has an increased 0.5 mm in/out value for the cases where upper second bicuspids are smaller than upper first bicuspids.

## Victory Series™ Lower Second Bicuspid Tubes

Appliances placed on lower second bicuspids frequently encounter occlusal interference during the early stages of treatment. Included in the MBT Versatile+ Appliance System is the Victory Series™ Lower Second Bicuspid Tube. As a tube, there are no tie-wings because ligation is not necessary, reducing the profile of the appliance on the tooth (Fig. 8).

**Figure 8**

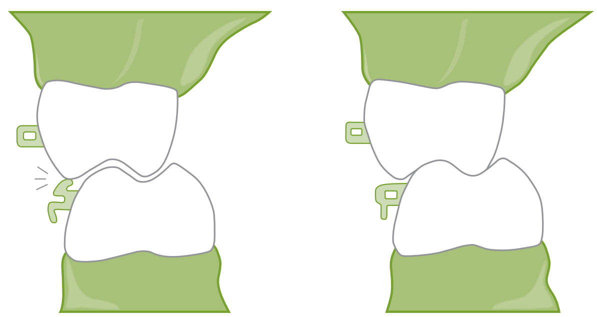


**Figure 8:** There is less chance of occlusal interference from tubes.

Victory Series™ Lower Second Biscuspid Tube

# Versatility of the MBT™ System Appliances

One of the strengths of the MBT™ Versatile+ System is the set of options that allow for modifications to meet an individual patient's treatment needs. A few of the most frequently used options are listed here.

- The upper central brackets offer increased torque to help prevent torque loss, and depending on the torque needs of the individual patient, a +17° or +22° bracket option is available.
- The upper lateral bracket can be inverted 180° to provide -10° of torque. This is especially useful when laterals are palatally displaced. The inverted value helps bring the root forward with the crown.
- The upper and lower cuspids can be inverted 180°. Applying +6° on the lowers and +7° on the uppers is especially useful for patients who lack adequate alveolar bone on the labial surface of the cuspid region, or when cuspid roots are prominent and possibly showing gingival recession.
- Another option on the cuspid teeth is the 0° torque bracket. These are especially useful in extraction cases to help maintain the cuspid roots centered in the alveolar process.
- When upper second bicuspids are smaller than first bicuspids, there is an alternative bracket with an additional 0.5 mm in the in-out dimension. When lower second bicuspids will likely create occlusal interference between their appliance and the upper arch, a lower second bicuspid tube is a possibility.
- Upper second buccal tubes may be placed on upper first molars when a headgear tube is not needed. Lower second buccal tubes may be placed on lower first molars in cases of occlusal interference with the upper first molars: the smaller size and elimination of tie-wings may provide the additional space required.

# MBT™ System Appliances

## Ligated Appliances

**Victory Series™ Brackets:** This mid-sized bracket provides an excellent combination of comfort, control and aesthetics. It is most beneficial in cases with smaller teeth and minimal to moderate degrees of difficulty.

**Victory Series™ Low Profile Brackets:** The Victory Series Low Profile Bracket has also become a popular treatment choice, featuring reduced bracket height for reduced occlusal interference. Features include torque-in-base and tie-wing undercut areas deep enough for double ligation.

**Clarity™ Metal-Reinforced Ceramic Brackets:** The Clarity ceramic bracket blends nicely against the tooth surface and provides excellent aesthetics. It features a metal slot which greatly minimizes breakage and allows for better sliding mechanics. Most importantly the bracket has a stress concentrator in the base of the bracket for ease of removal.

## Self-Ligating Appliances

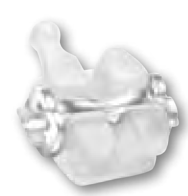
**SmartClip™ Self-Ligating Brackets:** For those preferring treatment in a self-ligating environment, SmartClip brackets are a versatile choice. These brackets feature a true-twin design and their integration in the MBT Versatile+ Appliance System is extensively detailed in a text by Dr. Hugo Trevisi: "SmartClip™ Self-Ligating Appliance System – Concept and Biomechanics" (REF. 014-508).

**Clarity™ SL Self-Ligating Brackets:** For aesthetic treatment and self-ligation, Clarity SL Self-Ligating brackets combine the design and treatment features of the SmartClip bracket with the popular translucent appearance of the Clarity bracket, for an uncompromising treatment choice.

Victory Series™ Low Profile Bracket

Clarity™ Metal-Reinforced Ceramic Bracket

SmartClip™ Self-Ligating Bracket



Clarity™ SL Self-Ligating Bracket

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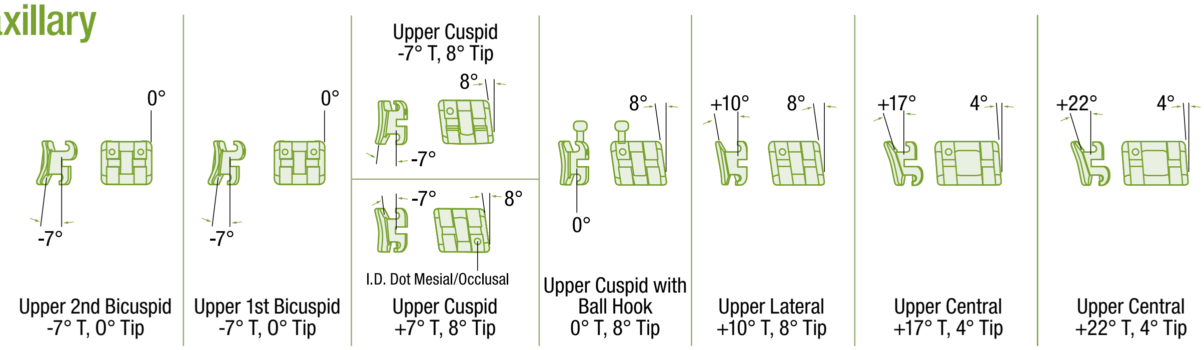
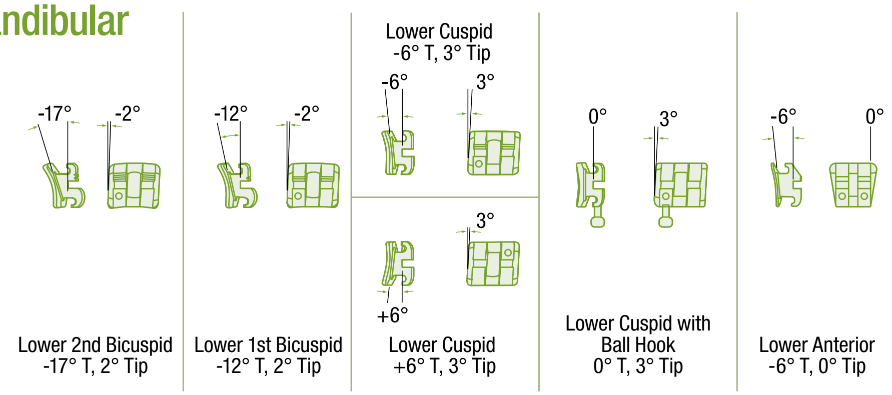
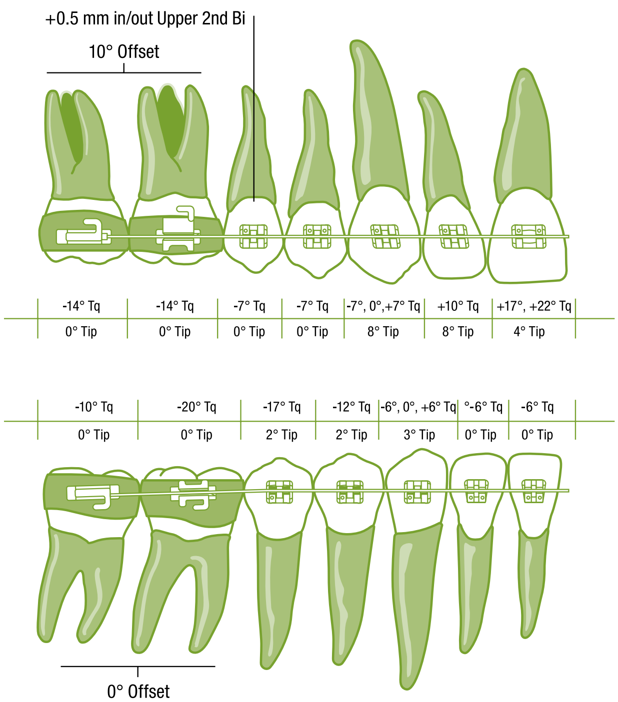
# MBT™ Versatile+ Appliance System

## Maxillary




## Mandibular

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# Treatment Challenge: Treating to a Stable Arch Form, Efficiently

Orthodontic alignment of the teeth in an arch form that will retain its form over time is a fundamental challenge in treatment. The difficulty in arriving at a quality result, consistently and efficiently, lies in the interrelationship of three axioms of arch form management:



- Due to multiple human variables, there is no one single ideal arch form that will accommodate all patients.
- Treating patients to an arch form that differs from their natural arch form will likely result in some relapse.
- While the best result is a personalized arch form for each patient, it is not the most efficient route. Therefore a system is needed that addresses the important factors in arch form variability without requiring customization.

The MBT™ Versatile+ Appliance System offers a set of three arch forms that are based on over a century's research regarding arch form management.

## The Foundation of Standard Arch Forms

Bonwill[1] attempted a standardized approach to arch form design in 1885, working from the observation of a tripod shape of the lower jaw. He noted that the lower jaw formed an equilateral triangle with the base reaching from condyle to condyle and the sides reaching to the midline of the central incisors. He also stated that the bicuspids and molars formed a straight line from the cuspids to the condyles.

Building on the foundation set by Bonwill, Hawley in 1905 proposed a geometric approach to ideal arch form construction. He proposed that the six anterior teeth lie along the arch of a circle with a radius equaling their combined widths. From the circle he formed an equilateral triangle that had a base at the inter-condylar width. He then suggested that the bicuspids and molars be aligned along the triangle's straight lines. Hawley did note, though, that this proposed method for developing an ideal arch form length was merely a guide and was not intended to be a strict method to determine arch form.

Angle[3], in 1907, did not consider the Bonwill-Hawley arch form to be worth more than a general guide to find the true line of a patient's occlusion. He defined his "line of occlusion" as "the line with which, in form and position according to type, the teeth must be in harmony if in normal occlusion." The form, he said, resembled a parabolic curve that varied greatly due to different human variables, reducing the merit of a single ideal arch arising from Bonwill and Hawley's work. The first order bends required in the arch form for accurate tooth positioning were, from Angle's perspective, examples of why the straight line design from cuspid to third molar was not accurate. He stated that a straight line extended from the cuspid to the mesio-buccal cusp of the first molar, but then there was a natural curve within the molar area.

In 1934, Chuck[4] reinforced the concept that human variation in arch form refutes the Bonwill-Hawley arch form's applicability to each patient, but suggested it could work as a template

Figure 1

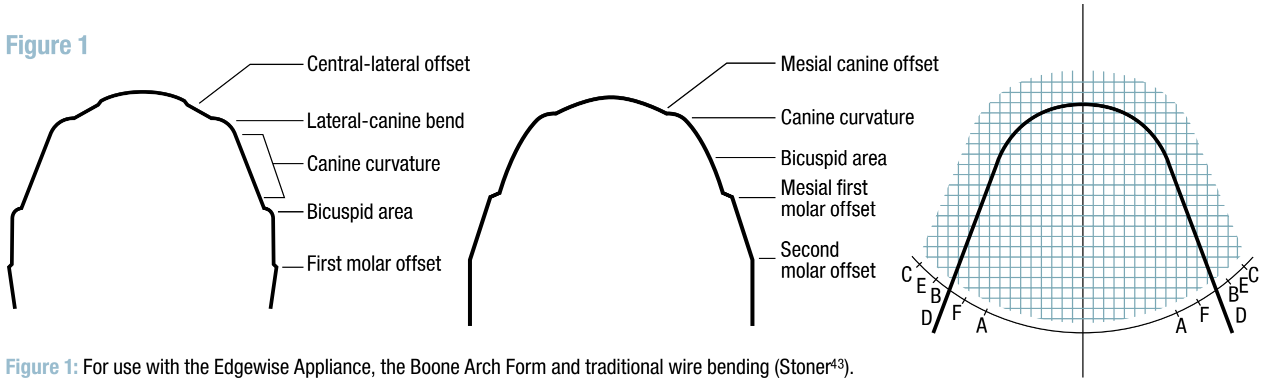



**Figure 1:** For use with the Edgewise Appliance, the Boone Arch Form and traditional wire bending (Stoner[43]).

to create customized arch forms. Chuck superimposed the arch form onto a millimeter grid and followed Angle's method to create arch forms. Boone[5] developed a similar template in 1963, and over the years the Bonwill-Hawley arch form has served as the basis of arch form construction for edgewise orthodontists. Most orthodontic manufacturers now offer a "standard" arch form in this shape.

## The Catenary Curve

In 1942, Gray's Anatomy[6] made the following statement about the human arch form: "The maxillary dental arch forms an elliptical curve... The mandibular dental arch forms a parabolic curve." But in 1949, MacConail[7] noted that it is impossible for an ellipse and a parabola to meet securely at every point, which is an issue when applying these shapes to orthodontic occlusion. He found that the ellipse-parabola concept is oversimplified and had no immediate relation to function. Instead, MacConail suggested that a catenary curve fit so many cases so well it could be interpreted as an "ideal curve" for common occlusions. A catenary curve is formed when a chain is suspended from two points of varying width (Fig. 2).

Scott[8], in 1957, studied the developmental anatomy of human dental arches and surrounding anatomic structures and agreed that the catenary curve is the normal shape of the human arch form. Burdi and Lillie[9] in 1966 reinforced the legitimacy of the catenary curve, although their research showed a number of arch forms outside the catenary shape. Musich[10] agreed that the catenary curve is the ideal human arch form and proposed a catenometer to build an arch perimeter. Most orthodontic manufacturers now offer a "tapered" arch form that is based on the catenary curve.

## The Ideal Arch form and Human Variability

Despite the advancement in developing an ideal arch template upon which to standardize arch form construction, there was at the same time a large body of research to demonstrate the great variability in the size and shape of the human arch form.

Figure 2

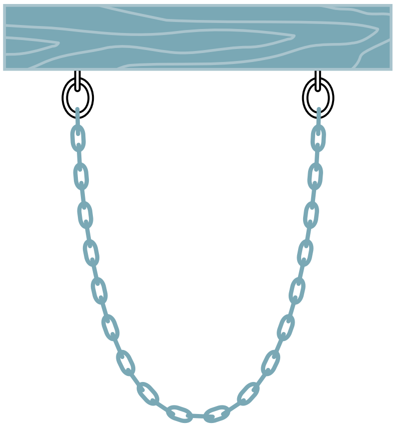


Figure 2: The catenary curve shape occurs when a chain is suspended from two fixed points.

Early on, as previously mentioned, Angle observed the number of variables that influence an individual's arch form and therefore saw any use of the Bonwill-Hawley approach to offer little more than a general approximation of the actual arch.

Brader[11], in 1972, attempted to propose an ideal arch form that allows for variability with an arch guide that had five arch forms, each form differing by the arch width at the second molars as measured from the facial, gingival surface. The maxillary arch form was simply one size larger than the mandibular arch form. This system, while more convenient, was met with criticism regarding excessive narrowing in the cuspids area, which often led to incisal wear of the cuspids.

In looking at skulls of both apes and humans, Hellman[12] found no relation between arch form and tooth size, and therefore questioned the approach of arch determination based on measurements of certain teeth. He concluded that a mathematical approach to addressing arch form shape was unsatisfactory. Wheeler[13] also observed that, while dental arches frequently fall within a general category of a parabolic shape, nothing anatomical could be converted into a mathematical method for defining an arch form.

Stanton[14] conducted a study of occlusions, leading to his observation that the Bonwill-Hawley arch form approach is flawed because most arch forms are open and closed, such as an ellipse or parabola. Izard[15] developed a method of arch form design based on ratios between arch width and facial depth. In his research, he found that about 75% of arch forms resembled an ellipse, 25% by a parabola, and 5% by a U shape. In the comparative study of arch predetermination methods and samples of "normal" occlusions performed by Remsen[16], he found that the parabola was the best representative shape of the anterior curvature of the dental arch. He did observe, however, that an arch fitting an exact pattern was more the exception than the rule.

Further investigating variability within a general arch form, White[17] compared the accuracy of selected standardized arch designs to 24 untreated ideal adult occlusions. He found that:

- The Bonwill-Hawley arch form had a good fit in 8.33% of the cases.
- The Brader arch form had a good fit in 12.50% of the cases.
- The Catenary curve had a good fit in 27.08% of the cases.

In his study, White also challenged the notion that the arch form must be symmetrical, and suggested that some amount of asymmetry should be incorporated into arch form design.

Finally, to answer whether a single ideal arch form exists for orthodontic treatment, Felton[18] et al analyzed the mandibular casts of 30 untreated normal cases, 30 Class I non-extraction cases, and 30 Class II non-extraction cases. After digitizing these casts and conducting a quantitative analysis, they concluded that no one arch form predominated any of the three sets of 30. They stated that the likely best path to long term stability was a customized arch form, because of the degree of variability in the arches.

The underlying message that seems to run through these and other clinical experiences and published research is that there does not appear to be a single ideal arch form that can be applied to all orthodontic cases, due to the degree of human variability. Further, when a patient's original arch form is modified to fit a standard shape, there is a strong tendency for the arch form to return to its original shape after active treatment is completed.

Figure 3

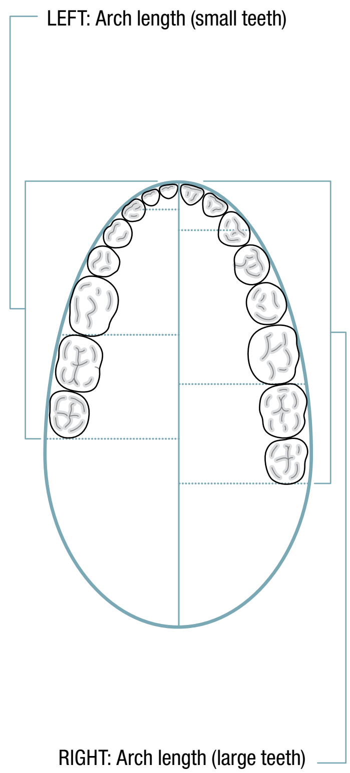



Figure 3: Brader applied the anterior section of a trifocal ellipse to develop an arch form.

## Relapse as a Result of Arch Form Changes

In 1969, Riedel[19] included a literature review in a chapter on retention in Graber's text on the topic of studies of stability in arch form. His review included many authors[20-35] who concluded that when inter-cuspid and inter-molar width had been changed in orthodontic treatment, there was a strong tendency for the teeth to return to their pre-treatment position. From this review, Reidel offered a number of theories about retention.

One was that “arch form, particularly in the mandibular arch, cannot be permanently altered during appliance therapy.” This comment was made primarily regarding non-extraction cases. In extraction cases, a number of authors[36-39] found that inter-molar width decreased post-treatment.

In 1974 Shapiro[40] analyzed changes in arch length, inter-cuspid width and inter-molar width in 22 non-extraction cases and 58 extraction cases after treatment and post-retention. He made the following findings:

- Mandibular inter cuspid width displayed a strong tendency to return to its pretreatment dimension in all groups save the Class II, division 2 group.
- Mandibular arch length was reduced substantially in all groups post-retention, although less in the Class II, division 2 group than the Class I and Class II division 1 groups.
- Comparing pretreatment to post-retention, mandibular inter-molar width decreased in extraction cases more than in non-extraction cases, but both demonstrated a trend towards the inter-molar width pretreatment.

Similarly, in 1976 Gardner[41] reviewed inter-cuspid, inter-first bicuspid, inter-second bicuspid and inter-molar widths, plus arch length changes, in 103 cases, 74 of which were non-extraction and 29 were treated with the extraction of four first bicuspids. He made the following observations:

- Inter-cuspid width was expanded in treatment and had a strong tendency to return close to its pretreatment width in both non-extraction and extraction cases.
- Inter-first bicuspid width and inter-second bicuspid width demonstrated only a small amount of post-treatment decrease.
- Inter-molar width in non-extraction cases increased significantly in treatment and the width in extraction cases decreased significantly, but there were no changes post-retention in either group.
- Regarding arch length, the incisor to inter-molar distance decreased in treatment and continued to decrease slightly post-retention.

Conducting a computerized analysis of the shape and stability of mandibular arch forms, Felton[42] in 1987 found in 30 Class I cases and 30 Class II cases that 70% of the arches returned to their original shape in post-treatment.

In 1995, De La Cruz, et al[43] reviewed the long term changes in arch form of 45 Class I cases and 42 Class II Division 1 cases after orthodontic treatment and after at least 10 years post-retention. They concluded that:

- Arch forms tend to return to the pre-treatment shape after retention.
- The greater the change in treatment, the greater the tendency for post-retention change.
- Minimizing treatment change was not a guarantee of post-retention stability, however
- Individual variations were considerable: the patient’s pre-treatment, natural arch form seemed to be the best guide for a stable arch form post-treatment.

These studies all indicate that attempts to change a patient’s arch form in treatment likely results in relapse to the patient’s pretreatment shape over time. The change is most notably seen in the inter-cuspid width.

There is a need, then, for an arch form system that acknowledges and treats to the patient’s natural arch form to achieve a more stable result, while at the same time providing a reasonably simple and efficient system of arch form selection to reduce the complexity in individualized arch form customization.



# The MBT™ Versatile+ Appliance Arch Form System Solution

## Techniques for Success

Preformed archwires are an important element in employing efficiency within a practice. Even as some bends are necessary, in preformed archwires most of the needed bending has already been completed. To incorporate the efficiency of preformed archwires into a system of treatment, while at the same time considering the great variability in the human arch form and the instability that can come with changing a patient's arch form in treatment, the MBT™ Versatile+ Appliance System employs the following steps:

**A Settling Phase:** Near the end of treatment, as treatment progresses from rectangular wires to retainers, a step between those two events is the installation of an .014 Nitinol lower archwire and an upper 2×2 .014 stainless steel sectional wire, to be used in combination with light triangular elastics. Check with the patient every two weeks for a total of six weeks. This will allow both vertical tooth settling and upper and lower arch form settling, to allow a balance between the tongue and the peri-oral musculature. This approach may be modified as needed:

- If there were extractions, stabilize the extractions with figure 8 ligature wires to allow settling.
- If the maxillary arch was expanded in treatment, include a removable palatal plate to allow settling in its expanded state.
- If anterior relapse is expected, such as in Class II Division 1 cases, install a full .014 archwire bent back behind the most distal molars. This will slow settling, but will help to counteract the possible relapse.

**Lower Retainers:** Apply lower bonded retainers to reduce the tendency for lower incisor relapse, which is a common occurrence.

**Upper Retainers:** If the lower arch seems to be narrowing relatively to the retained upper arch, remove the upper retainer for a period of two to four weeks. This can allow the settling of the upper arch in relation to the lower arch. Once adjustment seems stable, a new upper retainer can be installed.

Each of these steps will help to make the use of preformed archwires more effective in the goal to arrive at a stable arch form.

## Essential Elements of Preformed Archwires

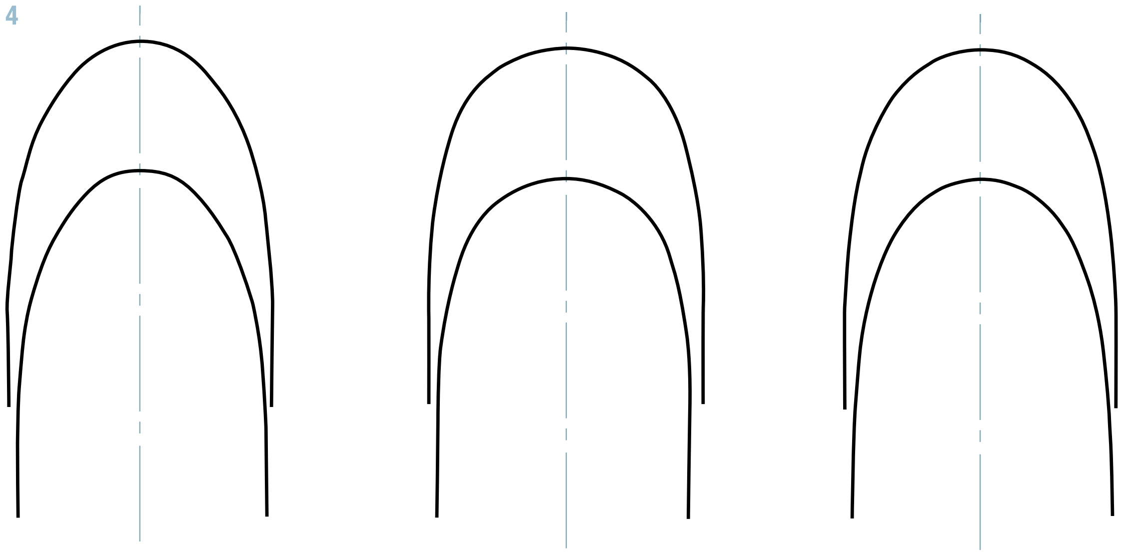
Arch form analyses from multiple studies indicate four basic components of any arch form:

- **Anterior Curvature –** All authors have generally observed some amount of curvature in the anteriors. The degree of this curvature is influenced by the degree of the inter-cuspid width in the arch.
- **Inter-Cuspid Width –** Many have observed this dimension to be the most critical, and it is the area of most significant relapse if it is changed. Therefore, the shape of the preformed archwire chosen should correspond closely to the desired width between the cuspids.
- **Inter-Molar Width –** Treatment changes in the molar region tend to be somewhat more stable than changes elsewhere in the arch, so it is less critical in arch form selection. A preformed archwire can likely work as a good starting template for a case, which can be widened or narrowed in this dimension depending on the individual patient's needs.
- **Cuspid to Second Molar Curvature –** Over the years, this dimension has varied from a straight line (Bonwill-Hawley) to a strong curve (Brader). Most studies seem to fall between these two arch form shapes, allowing for a gradual curvature between cuspids and second molars.

## Three Arch Form Shapes

In reviewing the literature regarding arch forms, a significant portion of the studies indicate only a few categories of arch forms as described by the researchers, which may be summarized into the forms Tapered, Ovoid and Square. When superimposed, the greatest variability among the three shapes is the inter-cuspid width, a range of about 5 mm. The posterior region of all three shapes are essentially similar, and can be widened or narrowed as needed. The MBT Versatile+ Appliance System offers archwires in all three of these basic

Figure 4



Tapered Arch Form – OrthoForm™ I Modified

Square Arch Form – OrthoForm™ II

Ovoid Arch Form – OrthoForm™ III

arch forms. Following is a general guideline to assist in the selection of each arch form.

**Tapered Arch Form:** Among the three, this arch form offers the most narrow inter-cuspid width. This form is especially ideal for patients with narrow arch forms and gingival recession in the area of the cuspids and bicuspids (most frequently found among adults). Another useful application of this arch form is in cases of partial treatment of only one arch, as it will help reduce the occurrence of expansion in the treated arch.

**Square Arch Form:** This arch form is especially practical for patients with broad natural arch forms. It can also be applied early in treatment in cases that require buccal uprooting of the lower posterior segments and upper arch expansion. If over-expansion occurs, it is possible to change to the Ovoid arch forms later in treatment.

**Ovoid Arch Form:** With an inter-cuspid width between the other two forms, this form is intended, when employed with the retention and settling steps mentioned above, to maintain a stable arch form post-treatment.

3M Unitek offers diagnosis and chairside arch form templates to help select the best arch form for any individual patient.

**Diagnosis OrthoForm™**
**Arch Form Templates**
Clear templates for overlay on patient model.
**REF. 701-723** (3) in package

**Operatory OrthoForm**
**Arch Form Templates**
White templates for chairside use.
**REF. 701-724** (3) in package



# Treatment Challenge: Consistent, Accurate Bracket Placement

Of the many different factors that can influence the efficiency and quality of orthodontic tooth movement, bracket placement accuracy is perhaps the most important. The performance of the other factors – tip, torque, bracket dimensions, archwire selection, base fit, etc – are all very significantly influenced by the location of the bracket on the tooth. A system that allows for efficient, consistent, accurate bracket placement can have a significant impact on individual cases and on the orthodontic practice as a whole.

Historically, for preadjusted appliance brackets, a common method for placement has been to place the bracket such that the twin bracket tie-wings straddle the vertical long axis of the clinical crown, in parallel with the axis. The center of the bracket slot, then, is placed at the center of the clinical crown[1]. But this approach can lead to a number of errors in bracket placement.

## Bracket Horizontal, Axis and Base Errors

**Bracket Horizontal Errors:** If brackets are placed mesial or distal to the vertical axis of the clinical crown, it can lead to unwanted tooth rotation (Fig. 1). This may be remedied by visualizing or even drawing in a line through the vertical long axis of the crown from the facial surface or, with the use of a mouth mirror, the incisal or occlusal surface.

**Bracket Axis Errors:** If brackets are placed such that their tie-wings are not parallel to the long axis of the clinical crown, it can lead to unwanted crown tip (Fig. 2). This may be remedied by employing the same visualization or drawing techniques used to reduce horizontal errors.

**Bracket Base Errors:** If excessive adhesive remains underneath a part of the bracket base, the bracket will remain on the tooth at an unwanted angle, likely leading to unwanted torque or rotation (Fig. 3). This may be remedied by pressing fully on the bracket once it has been placed to ensure that excessive adhesive flows out from beneath the bracket.

**Figure 1**

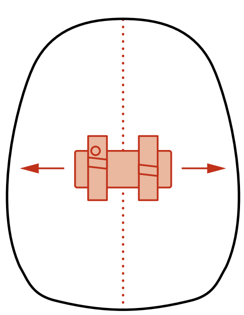


**Figure 1:** Horizontal bracket placement errors can result in unwanted rotation, but are avoided with attention to technique.

**Figure 2**

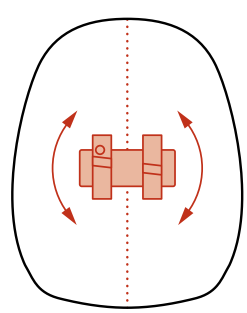


**Figure 2:** Axial bracket placement errors can result in unwanted tip, but are avoided with attention to technique.

**Figure 3**

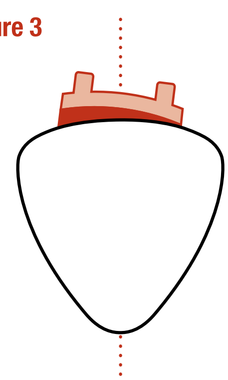


**Figure 3:** Excessive adhesive under the bracket base can result in rotation errors, but are avoided with attention to technique.

## Accurate Vertical Bracket Placement

More challenging, however, is accurate vertical bracket placement, in part because there are so many variables that can make it difficult to estimate the true center of the clinical crown. Placing a bracket too gingivally or too occlusally on the tooth relative to the center of the clinical crown can lead to unwanted extrusion or intrusion of the teeth, plus unwanted torque and in/out errors (Fig. 4).

There are a number of factors that make simple visualization of the clinical vertical center of the clinical crown deceptively difficult.

**Partially Erupted Teeth:** The true center of a clinical crown is difficult to identify when the tooth hasn't yet fully erupted (Fig. 5). The likely result is a placement that is too occlusal relative to the true center, especially with bicuspids and lower second molars.

**Inflamed Gingiva:** Gingival inflammation (Fig. 6) reduces the visible portion of the clinical crown, leading again to a likely misplacement too occlusally on the tooth relative to the true center[2].

**Figure 4**

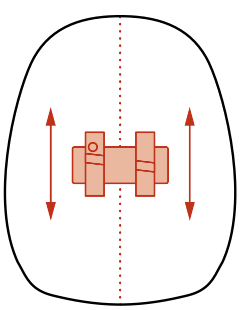


**Figure 4:** Avoiding vertical errors is not as straightforward. Placing brackets too gingival or too occlusal from the center of the clinical crown can be the result of a number of factors.

**Figure 5**

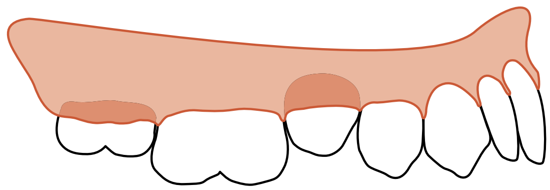


**Figure 5:** The center of the clinical crown is more difficult to visualize in partially erupted teeth in young patients.

**Figure 6**

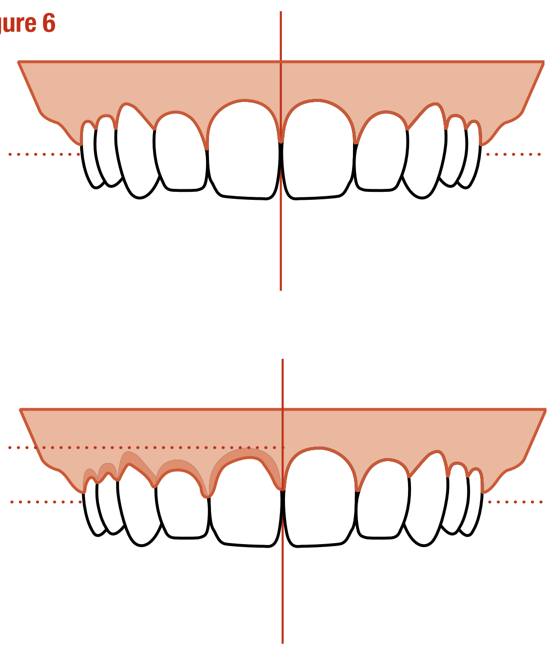


**Figure 6:** Inflamed gingival causes foreshortening, which can effectively reduce the length of the clinical crowns, making the center difficult to ascertain. The bottom image is the same case as the top image, but with gingival inflammation in the upper right quadrant.

3

Figure 7

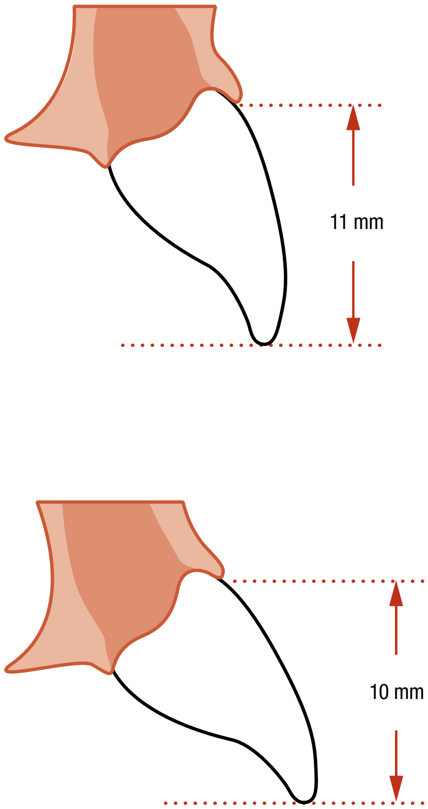



Figure 8

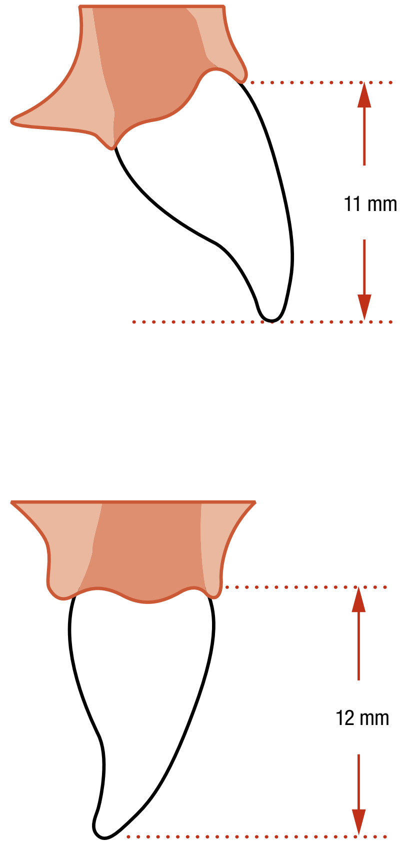



**Figure 7:** Teeth with roots that are lingually displaced can reveal shorter clinical crowns.

**Figure 8:** Teeth with roots that are facially displaced can reveal longer clinical crowns.

**Displaced Roots:** Teeth with palatally or lingually displaced roots (Fig. 7) have more gingival tissue covering the clinical crown so that less of the total crown is visible. Again, that may lead to a placement too occlusally compared to the true center of the tooth. Facially displaced roots (Fig. 8), often in the cuspid area, result in the opposite difficulty: more of the tooth is exposed because of the root's orientation, potentially leading to a placement more gingivally to the tooth than the vertical center.

**Figure 9**

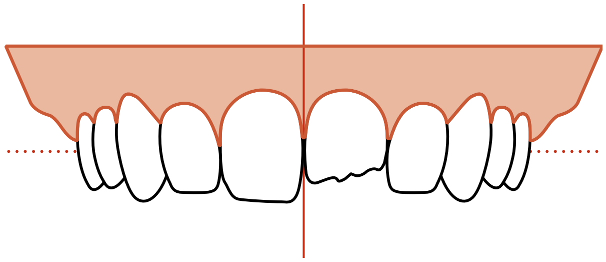


**Figure 9:** Incisors with fractures or tooth wear make it more challenging to determine the center of the clinical crown.

**Figure 10**

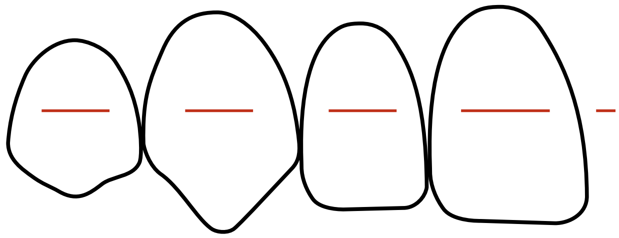


**Figure 10:** When cuspids have tapered clinical crowns, they do not occlude adequately with the opposing teeth.



**Fractures or Tooth Wear:** Because the clinical crown in these cases is shortened from the occlusal edge (Fig. 9), it may be difficult to determine the true center of the crown.

**Long Tapered Buccal Cusps:** Tooth shape is variable, and it is possible for cuspids or bicuspids to have long and tapered buccal cusps (Fig. 10), giving an inaccurate sense of the true size of the clinical crown to find its center.

**Long Clinical Crowns:** When certain clinical crowns are proportionately longer than the average length for that individual (such as with upper incisors), placement of a bracket at the center of the clinical crown may result in aesthetic and occlusal difficulties. If placed at the center, these teeth will look too long and interfere with the opposing dentition. In these cases, place the bracket incisal to the center of the oversized clinical crowns. The slight difference in the way the torque and in/out bracket thickness perform in this placement is minimal and can be corrected near the end of treatment.

**Short Clinical Crowns:** In the circumstances where certain teeth are proportionately shorter than the average length for that individual, difficulties opposite to the problems with proportionately long clinical crowns may occur. If the bracket is placed at the center of the clinical crown, aesthetically the tooth will look too short and functionally the tooth will not be in appropriate contact with the opposing dentition. In these cases, place the bracket gingival to the center of the undersized clinical crowns. As with proportionately long clinical crowns, the affect on the bracket's torque and other dimensions is minimal and can be corrected at the end of treatment.

There are, therefore, a number of circumstances where visually estimating the clinical crown's vertical center can result in inaccuracy and inconsistency. To reduce these occurrences, a system has been devised to increase accuracy without making the bracket placement process much more complex.

# The MBT™ Versatile+ Appliance System Solution

The Bracket Placement Chart seen in Table 1 is the result of research of published studies, thorough analysis of treated cases, and years of clinical experience to determine the vertical placement norms. Potential errors made because of the location of the gingiva are eliminated because all measurements are made from the occlusal edge of the teeth. This chart also allows for the complexity that can arise due to proportionally long or short teeth. This chart does not allow for measuring teeth with occlusal wear, or crowns with long, tapered cusps, but it can be used as a starting point, after which an appropriate millimeter adjustment is made, as appropriate for the case.



Use of the MBT™ Versatile+ Appliance Bracket Placement Chart is done by following these steps:

- **Step One –** Use dividers and a millimeter ruler to measure the clinical crown heights on the fully erupted teeth in the patient's study model.
- **Step Two –** Record these measurements, divide them in half and round to the nearest 0.5 mm. This will provide the distance from the occlusal surface to the vertical center of the clinical crown.
- **Step Three –** Review the Bracket Placement Chart. Find the row that has the greatest number of the recorded measurements, and use that row for bracket placement. Note again that in the case of disproportionately long or short teeth, the value in the Bracket Placement Chart's row may be larger or smaller than the recorded measurements. In this case, and in the case of occlusal wear or overly long tapered cusps, use the Placement Chart's measurement as a reference and make the appropriate millimeter adjustments from there.
- **Step Four –** Place the brackets while visualizing the vertical long axis of the clinical crowns for a vertical reference and the perceived center of the clinical crown as a horizontal reference.
- **Step Five –** Use a bracket placement gauge to confirm the vertical height of the brackets placed is aligned with the values in the Bracket Placement Chart. 3M Unitek offers a set of bracket positioning gauges that are an essential component to this bracket placement system (Fig. 12).
- **Step Six –** Ensure that the malocclusion receiving treatment does not create conflict between teeth in the upper arch and the appliances on the lower arch. If there is conflict, adjust the treatment plan accordingly, either with appliances such as bite plates, or a replacement or removal of the lower bracket.

**Figure 12**

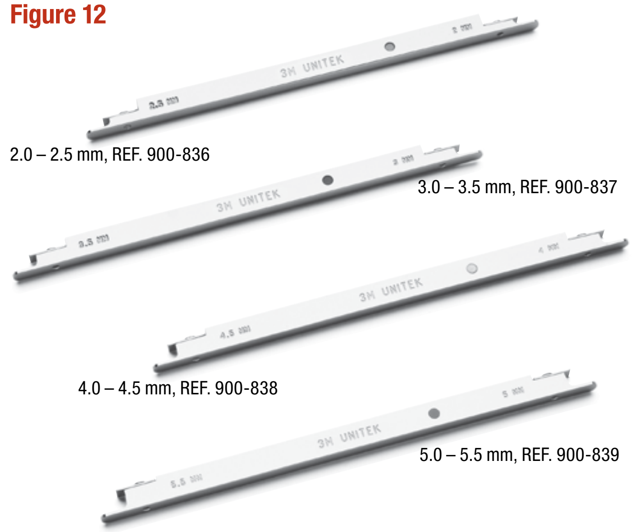
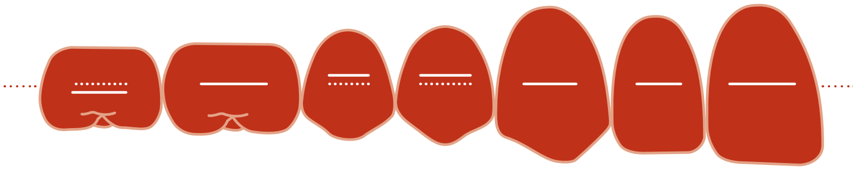


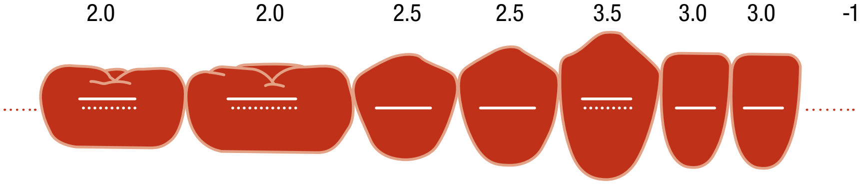

**Figure 12:** 3M Unitek Bracket Positioning Gauges are offered individually or as a kit of 4 instruments (REF. 900-841).

## Table 1: Bracket Placement Chart



| U7 | U6 | U5 | U4 | U3 | U2 | U1 | |
|---|---|---|---|---|---|---|---|
| 2.0 | 4.0 | 5.0 | 5.5 | 6.0 | 5.5 | 6.0 | +1.0 mm |
| 2.0 | 3.5 | 4.5 | 5.0 | 5.5 | 5.0 | 5.5 | +0.5 mm |
| 2.0 | 3.0 | 4.0 | 4.5 | 5.0 | 4.5 | 5.0 | Average |
| 2.0 | 2.5 | 3.5 | 4.0 | 4.5 | 4.0 | 4.5 | -0.5 mm |
| 2.0 | 2.0 | 3.0 | 3.5 | 4.0 | 3.5 | 4.0 | -1.0 mm |

| L7 | L6 | L5 | L4 | L3 | L2 | L1 | |
|---|---|---|---|---|---|---|---|
| 3.5 | 3.5 | 4.5 | 5.0 | 5.5 | 5.0 | 5.0 | +1.0 mm |
| 3.0 | 3.0 | 4.0 | 4.5 | 5.0 | 4.5 | 4.5 | +0.5 mm |
| 2.5 | 2.5 | 3.5 | 3.5 | 4.5 | 4.0 | 4.0 | Average |
| 2.0 | 2.0 | 3.0 | 3.0 | 4.0 | 3.5 | 3.5 | -0.5 mm |
| 2.0 | 2.0 | 2.5 | 2.5 | 3.5 | 3.0 | 3.0 | -1.0 mm |



# Summary

Direct visualization for bracket placement has proven to be reasonably accurate, and it is an efficient technique for direct or indirect bonding methods. The vertical dimension, however, poses a number of variables that can challenge the accuracy of bracket placement. The MBT™ Versatile+ Appliance System provides, through the use of the Bracket Placement Chart and the Positioning Instruments, helpful tools that reduce the potential for placement error and provide a means of greater consistency and accuracy. Incorporation of these tools into the practice's placement methods involves relatively few new process steps, but can contribute to the overall success of a patient's treatment as a result.

# References

## 1 Torque and Tip


1. Andrews LF. The six keys to normal occlusion. Am J Orthod 1972; 62: 296-309.
2. 'A' Company catalogue, 'A' Company Orthodontics, 9900 Old Grove Road, San Diego, California 92131-1683, U.S.A.
3. Andrews LF. Straight-Wire-The Concept and Appliance; L. A. Wells Co., San Diego, California. 92107: 1989.
4. Sebata E. An orthodontic study of teeth and dental arch form on the Japanese normal occlusion. Shikwa Gakuho 1980; 80: 945-969. (In Japanese.)
5. Watanabe K, Koga M, Yatabe K, Motegi E, Isshiki Y. A morphometric study on setup models of Japanese malocclusions. Shikwa Gakuho 1996. (Department of Orthodontics, Tokyo Dental College, Chiba 261, Japan).
6. Roth R. Gnathologic concepts and orthodontic treatment goals. In: Technique and Treatment with Light Wire Appliances. Ed. Jarabak JR. St. Louis: CV Mosby, 1970, pp. 1160-1223
7. McLaughlin R., Bennett J., Trevisi H., The MBT™ Versatile+ Appliance System, series, 1998-2007 3M.
8. McLaughlin R., Bennett J., Trevisi H., Systemized Orthodontic Treatment Mechanics, St. Louis: CV Mosby, 2001, p. 44.


## 2 Arch Forms


1. Bonwill, W. G. A., Geometrical and mechanical laws of articulation, Tr. Odont. Soc. Penn., pp. 119-133, 1884-1885.
2. Hawley, C. A., Determination of the normal arch and its application to orthodontia, Dental Cosmos 47: 541-552, 1905.
3. Angle, E. H., Treatment of malocclusion of the teeth, ed. 7, Philadelphia, 1907, S. S. White Dental Mfg. Co.
4. Chuck, G. C., Ideal arch form, Angle Orthod., 4: 312-327, 1934.
5. Boone, G. N., Archwires designed for individual patients, Angle Orthod., 33: 178-185, July, 1963.
6. Gray's Anatomy, 28th ed., 1942.
7. Huggins, D. G., and Birch, R. H., A cephalometric investigation of upper incisors following their retraction, Amer. J. Orthodont., 50:852-856, 1964.
8. Scott, J. H., The shape of the dental arches, J. D. Res., 36: 996-1003, 1957.
9. Burdi, A. R., and Lillie, J. H., A catenary analysis of the maxillary dental arch during human embryogenesis, Anat. Rec., 154: 13-20, 1966.
10. Musich, D. R., and Ackerman, J. L., The catenometer: A reliable device for estimating dental arch perimeter, Am. J. Orthod., Vol. 63, 4: 366-375, April, 1973.
11. Brader, A. C., Dental arch form related to intra-oral forces: PR=C, Am. J. Orthod., 61: 541-61, 1972.
12. Hellman, M., Dimension vs. form in teeth and their bearing on the morphology of the dental arch, Int. J. Orthodontia 5: 615-651, 1919.
13. Wheeler, R. C., A textbook of dental anatomy and physiology, ed. 2, Philadelphia, 1950, W.B. Saunders Company, pp. 196-215, 352-406.
14. Stanton, F. L., Arch predetermination and a method of relating the predetermined arch to the malocclusion to show the minimum tooth movement, Int. J. Orthodontia 8: 757-778, 1922.
15. Izard, G., New method for the determination of the normal arch by the function of the face, Int. J. Orthodontia 13: 582-595, 1927.
16. Remsen, W. M., Coordinated arches: An investigation into the form and interrelationship of orthodontic arch wires, Master's Thesis, Temple University School of Dentistry, pp. 27-29, June, 1964.
17. White, L. W., Individualized ideal arches, J. Clin.Ortho., 12: 779-787, 1978.
18. Felton, M. J., Sinclair, P. M., Jones, D. L., Alexander, R. G., A computerized analysis of the shape and stability of mandibular arch form, Am. J. Orthod., 92: 478-483, 1987.
19. Riedel, R. A., Current orthodontic concepts and techniques, Graber, T. M., WB Saunders Co., 1969.
20. McCauley, D. R., The cuspid and its function in retention, Amer. J. Orthodont., 30:196-205, 1944.
21. Strang, R. H. W., Factors associated with successful orthodontic treatment, Amer. J. Orthodont., 38:790-800, 1952.
22. Graber, T. M., Postmortems in post-treatment adjustment, Amer. J. Orthodont., 52:332-352, 1966.
23. Andreasen, G., and Naessig, C., Experimental findings on mesial relapse of maxillary first molars, Angle Orthodont., 38:51-55, 1968.
24. Huggins, D. G., and Birch, R. H., A cephalometric investigation of upper incisors following their retraction, Amer. J. Orthodont., 50:852-856, 1964.
25. Mills, J. R. E., A long-term assessment of the mechanical retroclination of the lower incisors, Angle Orthodont., 37:165-174, 1967.

## 2 Arch Forms (continued)

26. Ludwig, M. K., An analysis of anterior open-bite relationship changes during and following orthodontic treatment, Angle Orthodont., 36:204-210, 1966.

27. Goldstein, A., The clinical testing of orthodontic results, Amer. J. Orthodont., 51:723-755, 1965.

28. Hagerty, R. F., Andrews, E. B., Hill, M. J., Mendelson, B. P., Karesh, S. H., Lifschiz, J. M., and Swindler, D. R., Prevention of dental arch collapse, Angle Orthodont., 34:53-57, 1964.

29. Baum, A. T., Orthodontic treatment and the maturing face, Angle Orthodont., 36:121-135, 1966.

30. Funk, A. C., Mandibular response to headgear therapy and its clinical significance, Amer. J. Orhtodont., 53: 182-216, 1967.

31. Freunthaller, P., Cephalometric observations in Class II, Division I malocclusions treated with the activator, Angle Orthodont., 37:18-25, 1967.

32. Lebret, L. M. L., Changes in the palatal vault resulting from expansion, Angle Orthodont., 35:97-105, 1965.

33. Sandusky, W. C., Cephalometric evaluation of the effects of the Kloehn type of cervical traction used as an auxiliary with the edgewise mechanism following Tweed's principles for correction of Class II, Division I malocclusion, Amer. J. Orthodont., 51:262-287, 1965.

34. Steadman, H. R., A philosophy and practice of orthodontic retention, Angle Orthodont, 37:175-185, 1967.

35. Amott, R. D., A serial study of dental arch measurements on orthodontic subjects, masters thesis, Northwestern Univ., 1962.

36. Arnold, M. L., A study of the changes of the mandibular intercanine and intermolar widths during orthodontic treatment and following a postretention period of five or more years, masters thesis, Univ. of Washington, 1963.

37. Bishara, S. E., Chadha, J. M., and Potter, R. B., Stability of intercanine width, overbite and overjet correction, Am. J. Orthod., 63: 588-595, 1973.

38. Welch, K. M., A study of treatment and postretetnion dimensional changes in mandibular dental arches, masters thesis, Univ. of Washington, 1956.

39. Shapiro, P. A., Mandibular arch form and dimension, Am. J. Orthod., 66: 58-70, 1974.

40. Gardner, S. D., Postreatment and postretention changes following orthodontic therapy, Angle Orthod., 46: 151-161, 1976.

41. Felton, M. J., Sinclair, P. M., Jones, D. L., Alexander, R. G., A computerized analysis of the shape and stability of mandibular arch form, Am. J. Orthod., 92: 478-483, 1987.

42. De La Cruz, A. R., Sampson, P., Little, R. M., Artun, J., Odont, Shapiro, P. A., Long-term changes in arch form after orthodontic treatment and retention, Am. J. Orthod., 107: 518-530, 1995.

43. Stoner, M. M., Lindquist, J. T., Current orthodontic concepts and techniques, Graber, T. M., WB Saunders Co., Chp. 6, pp. 350-370, 1969.

## 3 Bracket Placement

1. Andrews, L.F.: Straight-Wire – The Concept and The Appliance. Los Angeles. Wells Company. 1989.

2. McLaughlin, R. P. and Bennett, J. C.: "Bracket Placement with the Preadjusted Appliance" Journal of Clinical Orthodontics May 1995; 29: 302-311.

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