Understanding and Applying Wire-Bracket Angles

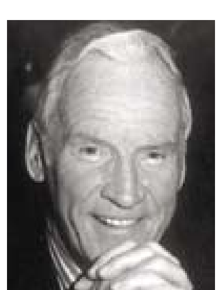
THOMAS F. MULLIGAN, DDS, MSD

The subject of wire-bracket angles is the basis for the application of force systems in orthodontics. For many years, orthodontists have had to bend archwires to create their force systems of choice. This was time-consuming, so the profession welcomed the introduction of prescription brackets, which eliminated the need for such bending. In essence, archwire shape has been exchanged for bracket design. At the time of this writing, there were more than 1,100 different prescription brackets on the market.

If the ultimate in bracket design were achieved, including features such as built-in tip and torque, there would be no need for so many different designs. Regardless of the designer or manufacturer, however, static equilibrium will always require balanced force systems. If the orthodontist is interested primarily in applying torque at a given time, the entire system must be balanced and, even more important, recognized. When a particular type of bracket design is disappointing, the search goes on for others that are more likely to meet the desired objectives.

Additional factors must be considered. For a bracket to meet the objectives for which it has been designed, the slot sizes and cross-sectional dimensions of the archwire must be absolutely accurate, but this is difficult to achieve in manufacturing. In spite of these weaknesses, prescription brackets do have a place in orthodontics—at least toward the end of treatment, when major tooth movements are no longer required.

Dr. Mulligan is in the private practice of orthodontics at 6843 N. Eighth Ave., Phoenix, AZ 85013; e-mail: tfmulligan@cox.net. This article is adapted by permission from his book, *Common Sense Mechanics in Everyday Orthodontics II* (CSM Publishing, 1040 E. Osborn Road, Phoenix, AZ 85014).



Regardless of whether a prescription bracket or a standard bracket with a so-called neutral slot is used, force systems will be formed as a result of the wire-bracket angles created when the archwire is inserted into the bracket slots. In everyday practice, these wire-bracket angles can easily be formed intraorally with a Tweed loop plier. The preferred angle to be formed in the archwire in any given plane of space—frontal, sagittal, or occlusal—is 45°. This angle is easy to read and can be used effectively with round wire without causing the wire to twist and turn within the slots.

Round wire is the best choice for almost all tooth movements discussed here, in spite of the bad name it has achieved over the years because of its inability to produce torque within the slot. The biomechanics involved recognize the need for torque, but given that a moment is the product of force and distance, it is not necessary to produce torque within the slot. It is often assumed that if a wire cannot produce a moment by twisting, it is incapable of producing torque. This is not true. Round wire can easily create moments at the brackets because of the angles formed in the sagittal plane of space (Fig. 1). Certain moments may appear to be in the wrong direction, but they are correct because they result from archwire resilience. With a square or rectangular wire, the moment is also a product of force and distance, although it is not usually visualized in this manner because the wire is first inserted into the molar tubes, as a matter of convenience (Fig. 2). Once inserted, the wire must be twisted to engage the anterior brackets.

Round wires may be incapable of producing torque within anterior bracket slots, but they can

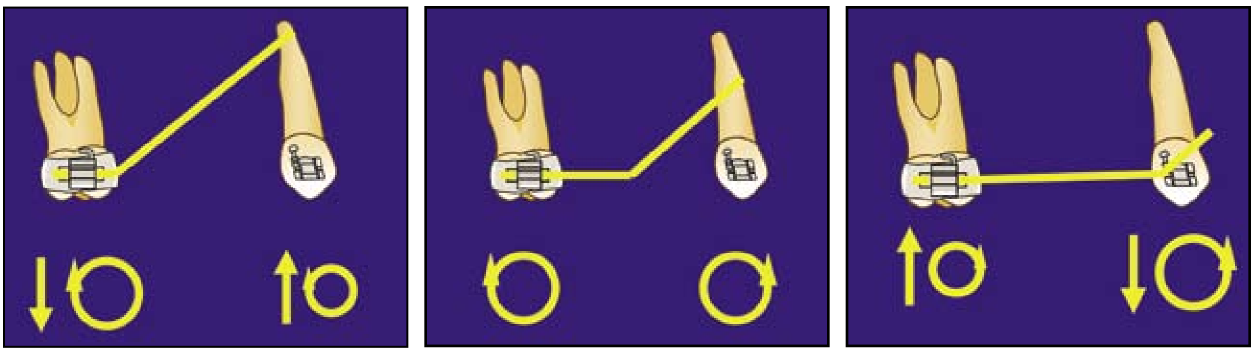


Fig. 1 Forces and moments produced by bends in three different locations.

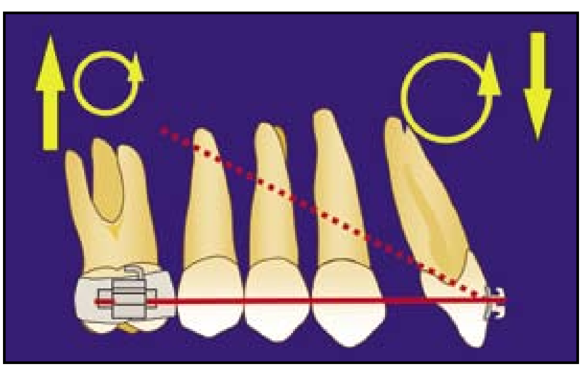


Fig. 2 Lingual root torque produced by twisting rectangular wire for insertion into anterior bracket slots.

create lingual root torque in the anterior segment. Intrusive forces acting through the incisor brackets may produce moments when exerted labially and perpendicular to the center of resistance in the incisor segment. The moments should actually be described as labial crown moments, because incisors will flare unless they are prevented from doing so, at which time the moments will produce lingual root movement. Before any of this can take place, it is essential to know the posterior moments. If the posterior moments in a partial appliance are greater than the anterior moment, the incisors will respond with lingual movement.

Wire-Bracket Relationships

The three most important wire-bracket relationships are the center bend, the off-center bend,

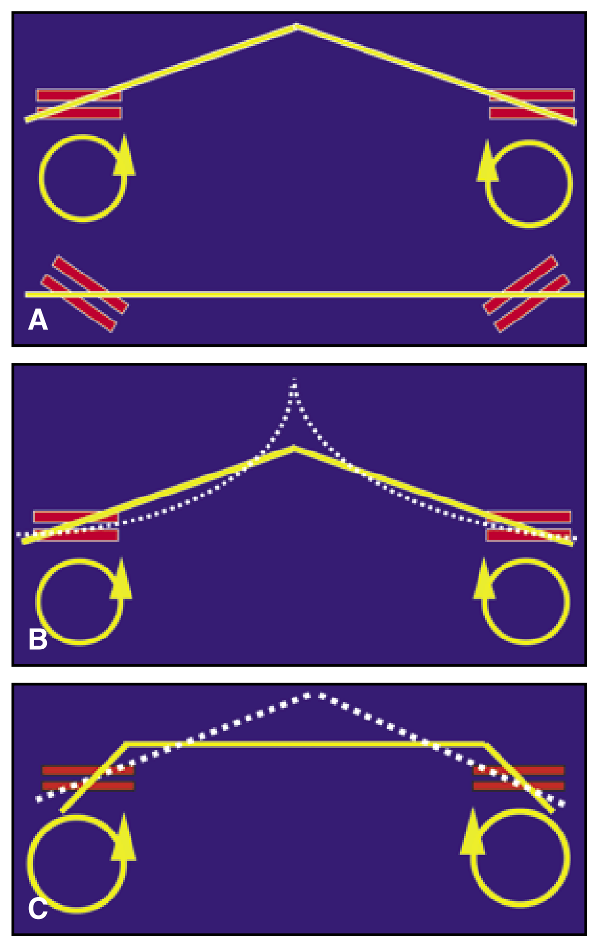


Fig. 3 A. Center bend. Note wire-bracket angles compared to straight wire and angulated brackets. B. Resilience of activated wire. C. Two off-center bends used to produce same force as center bend.

Fig. 4 Center bends used for root paralleling in extraction treatment.

and the parallel (step) bend. A fourth, the cantilever bend, has limited clinical application. Using a Tweed loop plier, 45° bends can be placed at different locations chosen by the orthodontist. Each location will produce different wire-bracket angles and a different force system. Unlike treatment with prescription brackets, a choice must be made as to which of three force systems will best solve the problem at hand. Obviously, the greater the interbracket distance, the more choices available for placing these bends.

The Center Bend

Whether the slots are prescription or neutral, the wire-bracket relationship determines the force system. The original malocclusion automatically creates wire-bracket angles because of malpositioned teeth.

Figure 3A shows the center bend, which is placed equidistant from the adjacent brackets. The wire-bracket angles seen with a center bend are

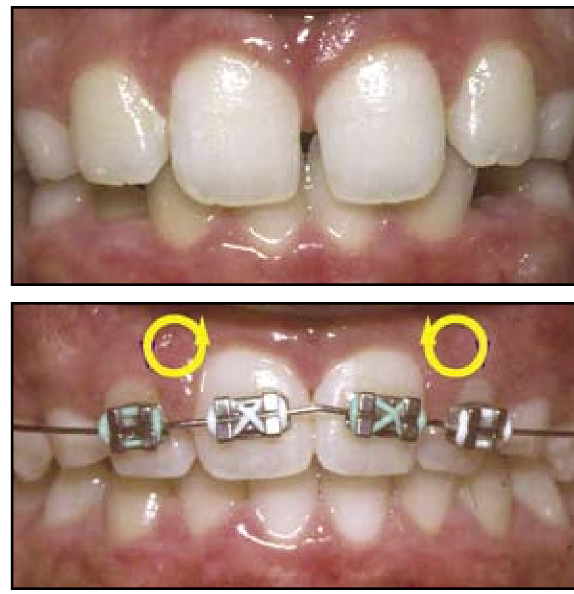


Fig. 5 Center bends used for root divergence in case with midline diastema.

the same as those seen when the wire is straight and the brackets are angulated. (Each angle is discussed here in relation to the brackets adjacent to the bend in question.) In this case, the force system consists of equal and opposite moments. The resilience of the activated wire is one of the major factors that can lead to a visual misinterpretation of force systems (Fig. 3B). Two off-center bends can be used to produce the same force system as a center bend (Fig. 3C).

Figure 4 shows the paralleling of roots following space closure in extraction treatment involving all four first premolars. The application is simple, but the response is significant.

Figure 5 shows a diastema between central incisors with converging roots. A center bend provides the equal and opposite moments required for root divergence and future stability following space closure. Crown movement always precedes root movement, until the spaces are closed.

Figure 6 shows the simultaneous divergence of all incisor roots with two sectional wires. A continuous wire cannot deliver four pure moments without creating vertical forces, but because a center bend is equivalent to two off-center bends

(Fig. 3C), a wire with a center bend between the two central incisors and a rectangular bypass segment with 45° bends at the lateral incisor brackets each provides the necessary moments for all four teeth and creates root divergence without the development of vertical forces. This bypass segment is one of the few instances where a rectangular wire is preferred.

Fig. 6 Simultaneous divergence of all incisor roots with two sectional wires.

Fig. 7 Two off-center bends used to parallel roots at extraction site.

Figure 7 shows the use of two off-center bends to produce paralleling moments at an extraction site. In this case, a military family did not know whether it would remain in town for a few weeks or several months. Therefore, the decision was made to extract teeth and permit eruption of the maxillary canines while retracting the mandibular canines. Because the mandibular second deciduous molars were still in place, the canines were retracted with off-center bends placed just mesial to the first molar tubes. (The bracket or tube closest to the bend represents the location of the larger moment, making the molars the anchor units during canine retraction.) The canine roots then required uprighting, however, so another off-center bend was added, allowing the roots to be paralleled before the eruption of the second premolars. Much can be accomplished while a patient's family is waiting for a job transfer or a military assignment.

The Cantilever Bend

Whereas the center bend is placed equidistant from two adjacent brackets, the cantilever bend is located one-third of the way between the two brackets, resulting in a long section and a short section. Again with level brackets, this bend position produces the same wire-bracket angles as when the wire is straight and the brackets are angulated (Fig. 8A). It is clear that determining the total force system by visually interpreting the

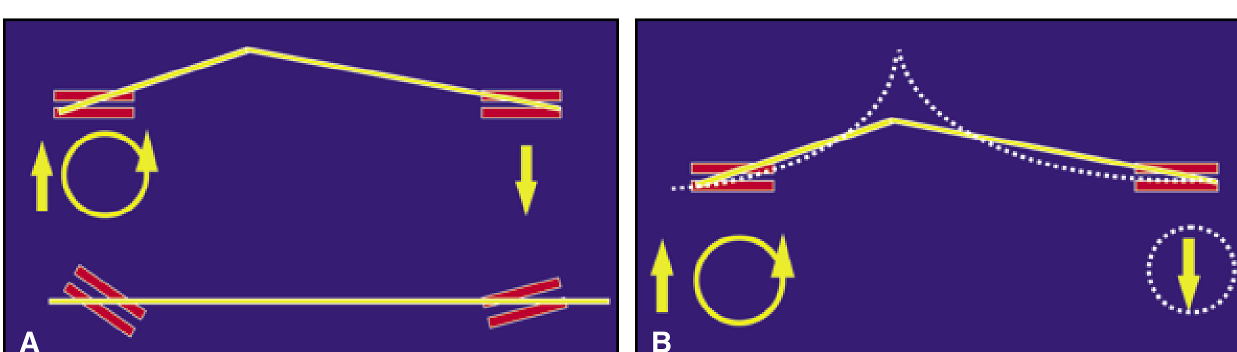


Fig. 8 A. Cantilever bend placed one-third of distance between brackets, resulting in long section and short section. B. Resilience of wire results in no angle at right bracket.

brackets is much more difficult. The straight wire with angulated brackets may be thought to contain moments at both brackets because of the angles formed when reading an archwire before activation. When the wire is activated by being inserted into the bracket slots, however, the resilience of the wire results in no angle at one of the brackets (Fig. 8B). This is true whether the slot size is .018" or .022" and regardless of interbracket distance.

The rules for the long section vs. the short section still apply: the long section points in the direction of the force produced, while the short section points in the direction opposite the force produced. The bracket located closer to the bend contains the larger moment, and the bracket farther from the bend contains the smaller moment, or no moment. Thus, the rule itself remains valid, but the information given is now more exact, as it identifies the smaller moment as zero.

Minor tooth movements can alter the force system. Figure 9 shows an anterior segment with a continuous overlay archwire. This can be applied in various ways to provide a pure force acting through the center of resistance, if desired. Figure 10 illustrates the most commonly used cantilever approach for canine intrusion. The archwire is placed under the incisal wings of the canine brackets and within the slots of the incisor brackets during overbite correction.

Although the cantilever bend has limited clinical application, it is one of the possible wire-bracket angles. When prescription brackets are used, this system may be encountered without being recognized, since the wire resilience is not visualized when reading wire-bracket relationships. The locations of the bends when the slots are level provide the most reliable determination of the force systems.

The Off-Center Bend

Although the cantilever bend is technically an off-center bend, it has been described separately because of its limited use. Figure 11 shows a force system quite different from those discussed so far. Although the smaller moment might appear to be in the wrong direction, Figure 11B again

Fig. 9 Cantilever bend used in anterior segment with continuous overlay arch.

Fig. 10 Cantilever intrusion of canine, with archwire placed under canine bracket wings.

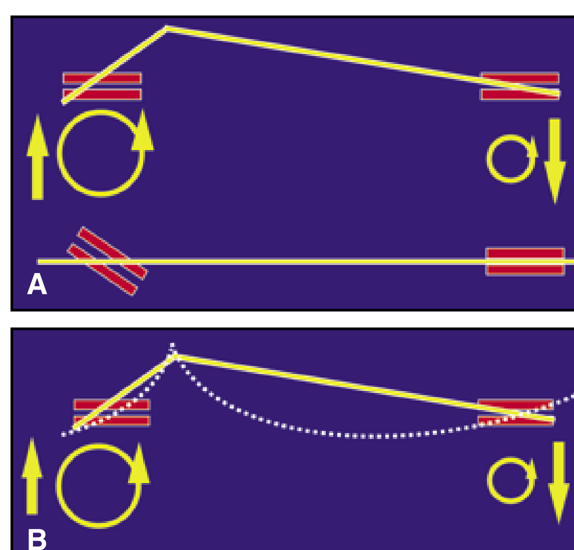


Fig. 11 A. Off-center bend. B. Resilience of activated wire responsible for counterclockwise moment.

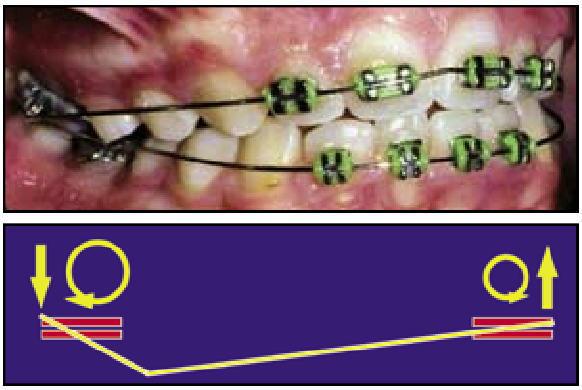


Fig. 12 Off-center tipback bend at molar.

Fig. 13 Off-center toe-in bend.

shows that archwire resilience is responsible for the counterclockwise moment, as the wire crosses the bracket at a completely different angle when activated than when simply visualized before activation (Fig. 11A). Forces and moments are predicted by the rules regarding long section vs. short section, although the smaller moment is more accurately described when the force systems are determined by the locations of the bends. Instead of referring to the moment simply as the smaller moment, the specific direction—clockwise, counterclockwise, or neutral—is indicated.

The clinical example shown in Figure 12 illustrates the use of an off-center tipback bend at the molar. As stated earlier, round wire cannot produce torque within incisor bracket slots. Although the moments shown previously were in the same direction when occurring in the sagittal plane of space, the anterior moment shown here is in the opposite direction because it is formed by an intrusive force acting labial to the center of resistance in the anterior segment, rather than by torque produced within the incisor bracket slots. The toe-in bend shown in Figure 13 is another form of off-center bend that produces the force and moment on the molar predicted by the short section in Figure 12. Changing planes of space does not affect the force system on the molar in either situation.

Figure 14 reveals an uncomplicated approach

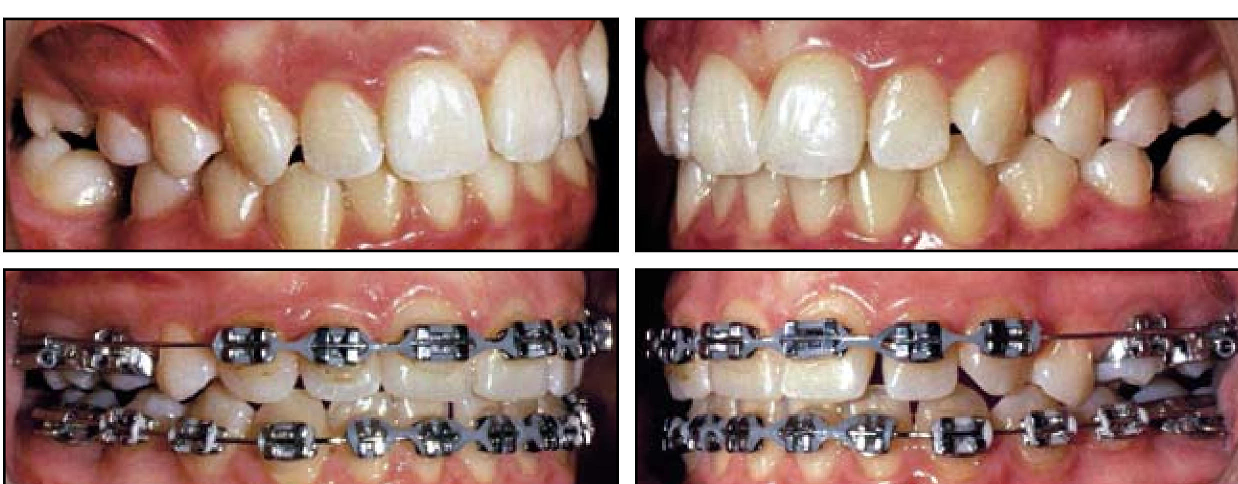


Fig. 14 Simultaneous rotation of molars and correction of crossbite.

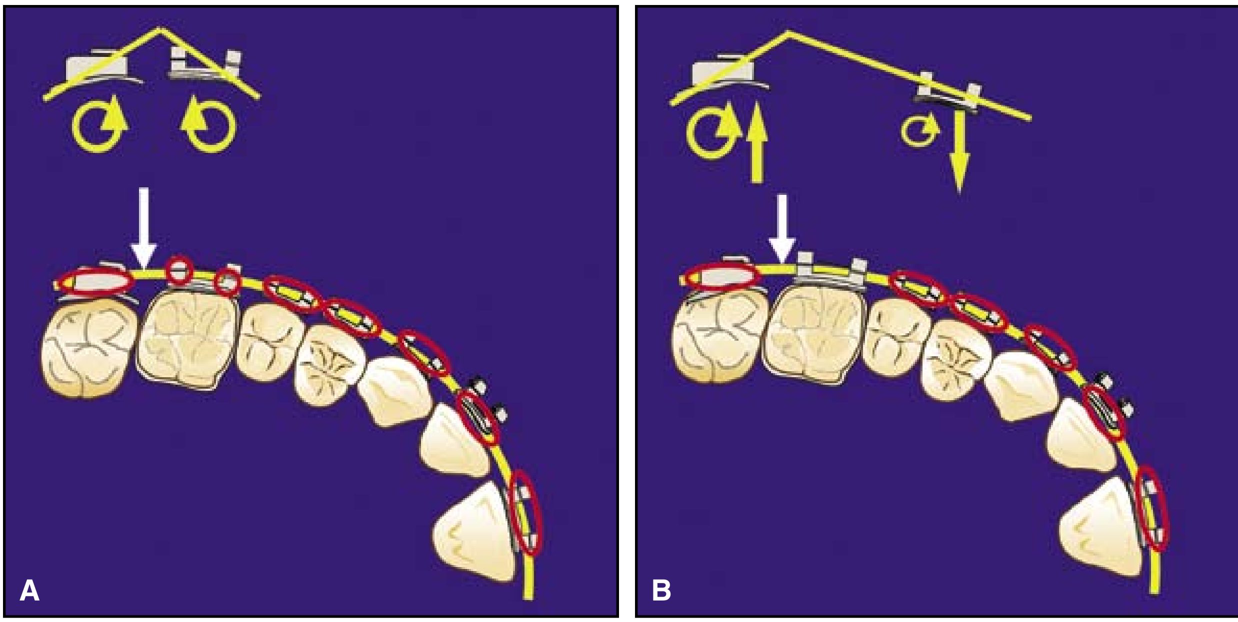


Fig. 15 A. Center bend used to rotate second molar, which now requires buccal movement. B. Center bend converted to off-center bend by removing first molar ligature, creating buccal force.

to rotating molars and correcting crossbites simultaneously. The secret lies in avoiding engagement of the archwire into the second premolar brackets, as seen in the upper arch. If all brackets were engaged, the off-center toe-in bends would become center bends and would therefore not provide buccal forces. Here, the toe-in bend, representing the short section, results in a force acting in the opposite direction. It is not uncommon to find molars that have drifted mesially before rotating and moving into lingual crossbite. This is an easy and effective method for simultaneous correction without the need for archwire removal.

In Figure 15A, the second molar has been rotated with a center bend. It now requires buccal movement, but there is no buccal force present. By simply removing the ligature on the first molar, the center bend is converted to an off-center bend, which introduces a buccal force in addition to the rotational moment at the molar (Fig. 15B). This is certainly a less time-consuming approach than removing the archwire to place a bend. In fact, these simplified procedures can make orthodontics more fun and less stressful.

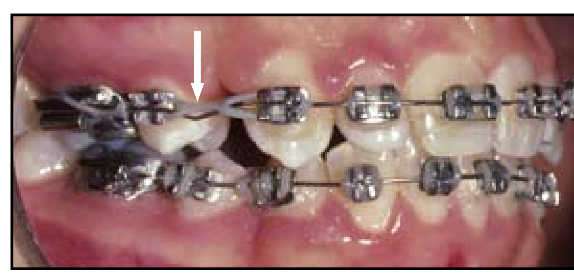


Fig. 16 Off-center bend placed for canine retraction becomes center bend after space closure.

The final clinical example of the off-center bend is shown in Figure 16. Locating the bend just mesial to the premolar bracket creates an anchor side to the extraction site, since the tooth closest to the bend has the larger moment. Once the space is closed, the moments become equal and opposite because the bend becomes centered. This change in the force system takes place without removing the archwire after the beginning of space closure.

In all these clinical examples, brackets were not added or removed to create a particular force system. For example, brackets may or may not be

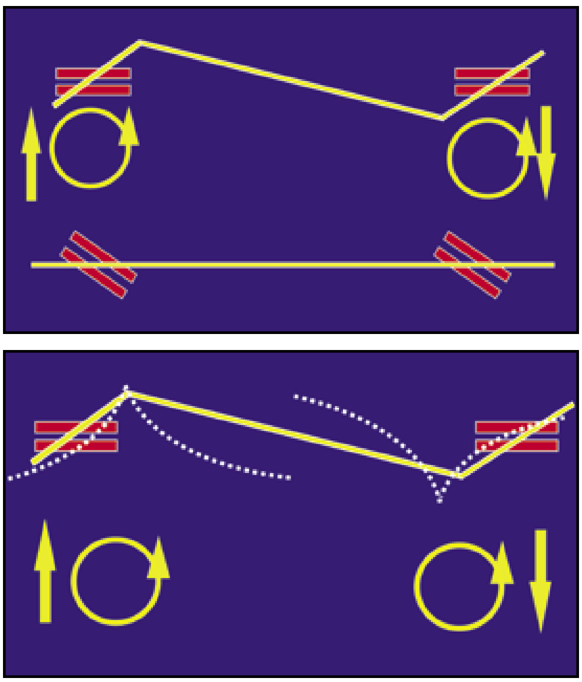


Fig. 17 Parallel (step) bend.

present on the premolars. The various wire-bracket angles may be introduced at any time without bracket changes to create the force system of choice.

The Parallel (Step) Bend

The final wire-bracket relationship to be introduced is the parallel relationship, also referred to as the step bend. Again, the wire-bracket angles are equal whether they involve activating bends and level slots or a straight wire and angulated slots (Fig. 17). Compared to the off-center bend, the step bend is nothing more than an additional bend placed at the adjacent bracket in the opposite direction, creating two parallel short sections. Of all the wire-bracket angles discussed, this relationship involves the greatest forces, since both of the moments are equal in magnitude and acting in the same direction. Therefore, the balancing forces must be greater to create a balancing moment, which must be equal and opposite to the net moment.

Because of the higher force magnitudes, the step relationship is most useful in the occlusal plane of space when positioning molars that have been displaced, as in crossbites. It may also be desirable in the treatment of older individuals, whose physiological response is usually not as helpful as in younger patients. The step bend can be applied in the sagittal plane of space when vertical forces do not pose a threat to the vertical dimension of the patient, as in brachycephalic individuals.

Figure 18 shows two examples of the step bend, with and without canine brackets. Technically speaking, the first example shows a genuine step relationship; the second shows bends applied in the same manner, but because a true step relationship does not exist, smaller forces are produced.

The higher force magnitudes from a step relationship can be effective in restoring central-groove relationships between the first and second molars and thus increasing the posterior transverse dimension (Fig. 19). On the other hand, the step bend can have distinct disadvantages in the sagittal plane of space when vertical problems are present. This is particularly true with full appliances; in many cases, the step bend will create the need for posterior high-pull headgear to be employed to overcome extrusive movements. If higher force magnitudes are not desirable, the off-center bend should be used.

The step bend creates force magnitudes as much as four times greater than those produced by a cantilever bend acting at the same interbracket distance with the same degree of activation. If a step bend is sectioned into two halves, each half constitutes a cantilever. In a cantilever bend, the load-deflection ratio is inversely proportional to the cube of the wire length. If the length is doubled, the force becomes one-eighth per unit of deflection. Therefore, if the length is reduced by half, the force will increase eightfold, assuming that the vertical deflection of the archwire remains constant. This helps explain why force levels are so high with step bends.

Of course, the archwire activation may involve different bends. In the step-down arch, an

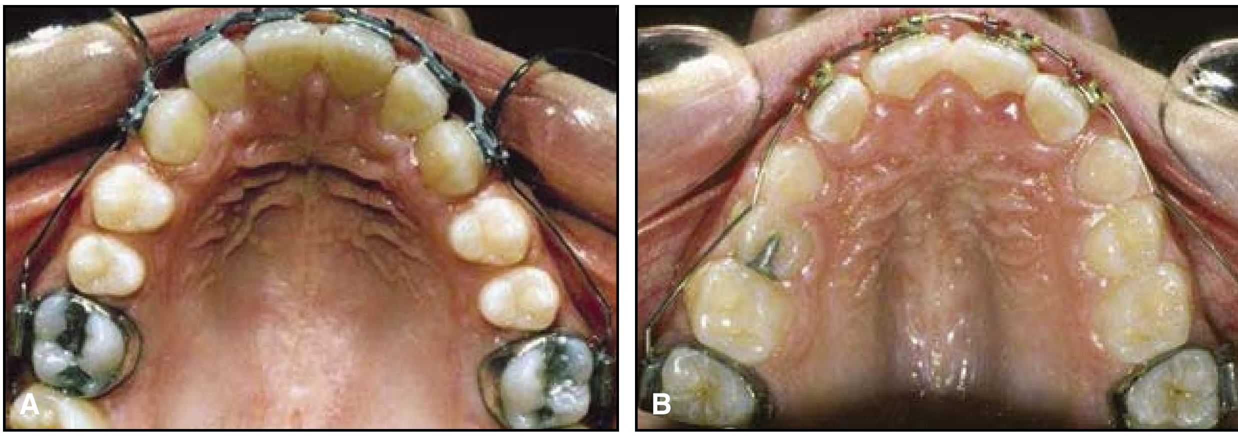


Fig. 18 Two examples of step bends. A. Canines bonded. B. Canines not bonded.

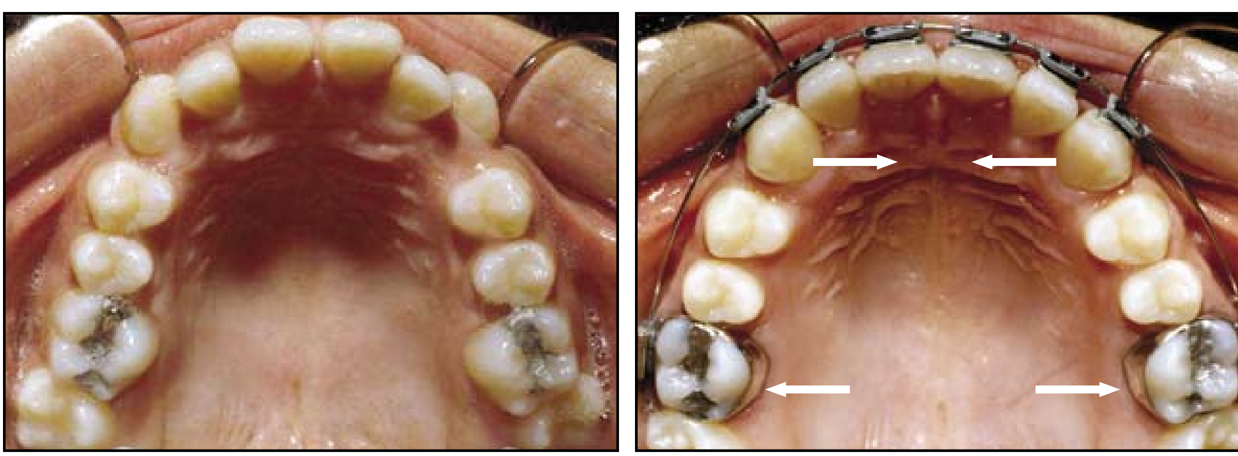


Fig. 19 Step bend used to increase posterior transverse dimension.

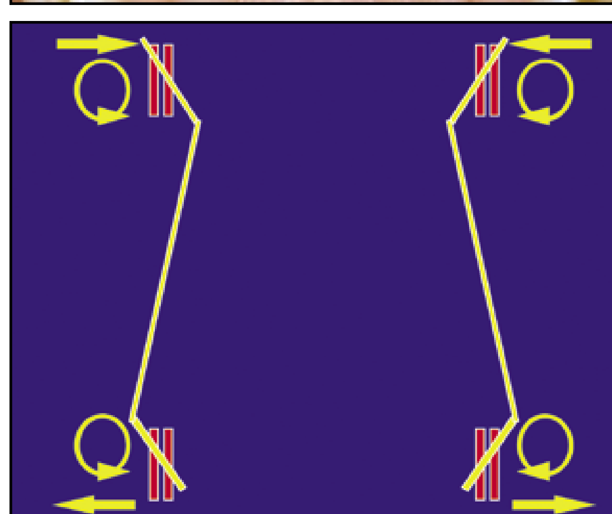


Fig. 20 In step-down arch, increased archwire length does not increase vertical deflection.

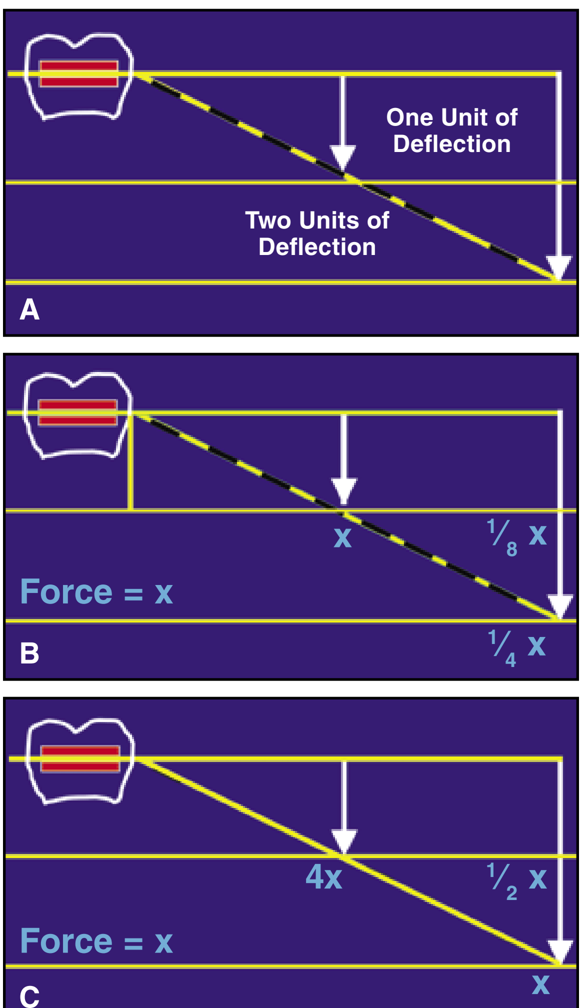


Fig. 21 A. Increased vertical deflection from use of tipback bend. B. Load-deflection ratio is one-fourth of original value. C. Half-length cantilever requires four times as much force for activation as cantilever twice as long with only one unit of vertical deflection.

increase in archwire length does not result in an increase in vertical deflection (Fig. 20). As the length of the wire doubles, it requires only one-eighth the force per unit of deflection. With the tipback bend, however, as the wire length doubles, vertical deflection also doubles. If the force is reduced to one-eighth per unit of deflection and there are now two units of deflection, then the new force is two times one-eighth, or one-fourth, of the original force (Fig. 21). A half-length cantilever will require four times as much force for activation as the same cantilever with twice the length and only one unit of vertical deflection (Fig. 21C).

Discussion

The cantilever bend has created confusion among many orthodontists because no moment is present at a bracket where one would appear to be, based on visual inspection of that bracket. If reading an archwire before it is inserted into the bracket slot indicates the presence of an angle, it is easy to assume that a moment must be present at that bracket. To further clarify the matter beyond the previous discussion of resilience, an additional explanation will be offered.

In the discussion of the various wire-bracket angles, the extremes involved the center bend, with equal and opposite moments, and the step bend, with equal moments in the same direction. The step bend also had balancing forces present, while none were required for the center bend. In Figure 22A, the brackets on the right involve opposite angular relationships. Figure 22B shows that as the bend moves from the centered position to the final step position, the new angle rotates counterclockwise. In Figure 22C, the bracket slot has moved from its original angular position to its final angular position, which is opposite the original. A wire cannot rotate from one angle to an opposite angle without passing through zero. At the zero point, shown in Figure 22D, only a pure force is present at the bracket; the archwire forms no angle with the slot.

Archwire resilience is responsible for the zero-angular relationship whenever a bend is placed at the one-third position between two brack-

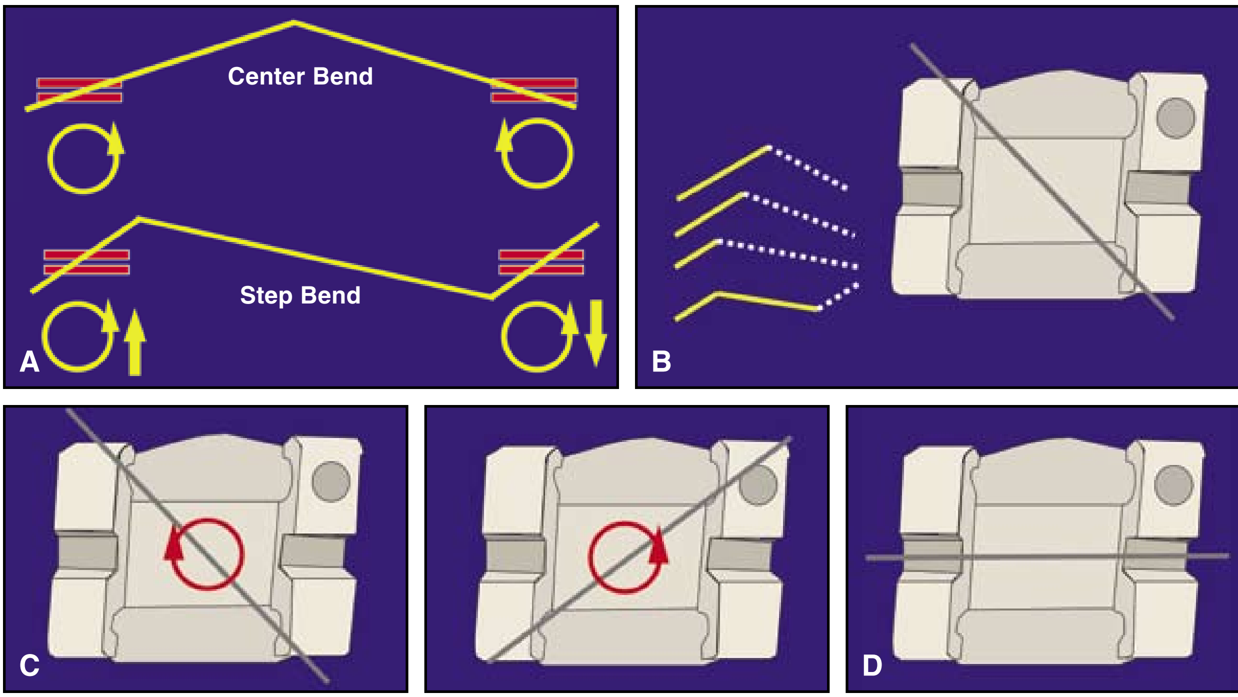


Fig. 22 A. Center bend and step bend. Brackets on right involve opposite angular relationships. B. Cantilever bend. As bend moves left, wire-bracket angle on right rotates counterclockwise. C. Bracket slot moves from original angular position to final angular position, opposite original. D. Zero point, with archwire forming no angle with bracket slot.

ets. This zero angle must exist somewhere between the two extremes of a clockwise moment in the center bend and a counterclockwise moment in the step bend (Fig. 22A).

Conclusion

Various wire-bracket relationships are possible in a loop-free wire, allowing the orthodontist to determine a force system by the location of an activation bend. Several of these angular relationships are extremely useful, particularly during treatment with partial appliances.

With the cantilever bend, the archwire may be placed under the wings of the brackets rather than in the slots, but this system has limited practical application. The center bend is especially useful for paralleling roots after space closure and for root divergence after diastema correction. The off-center bend is extremely effective in tooth retraction and protraction, as well as for buccal and lingual movements, rotational corrections, and vertical movements. The parallel or step bend produces the greatest force of all the wire-bracket relationships and is particularly useful in the occlusal plane of space. It can be disadvantageous in patients with vertical problems when used in the sagittal plane of space. This bend is especially effective for increasing the posterior transverse dimension and is the bend of choice for the older patient.

SUGGESTED READING

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