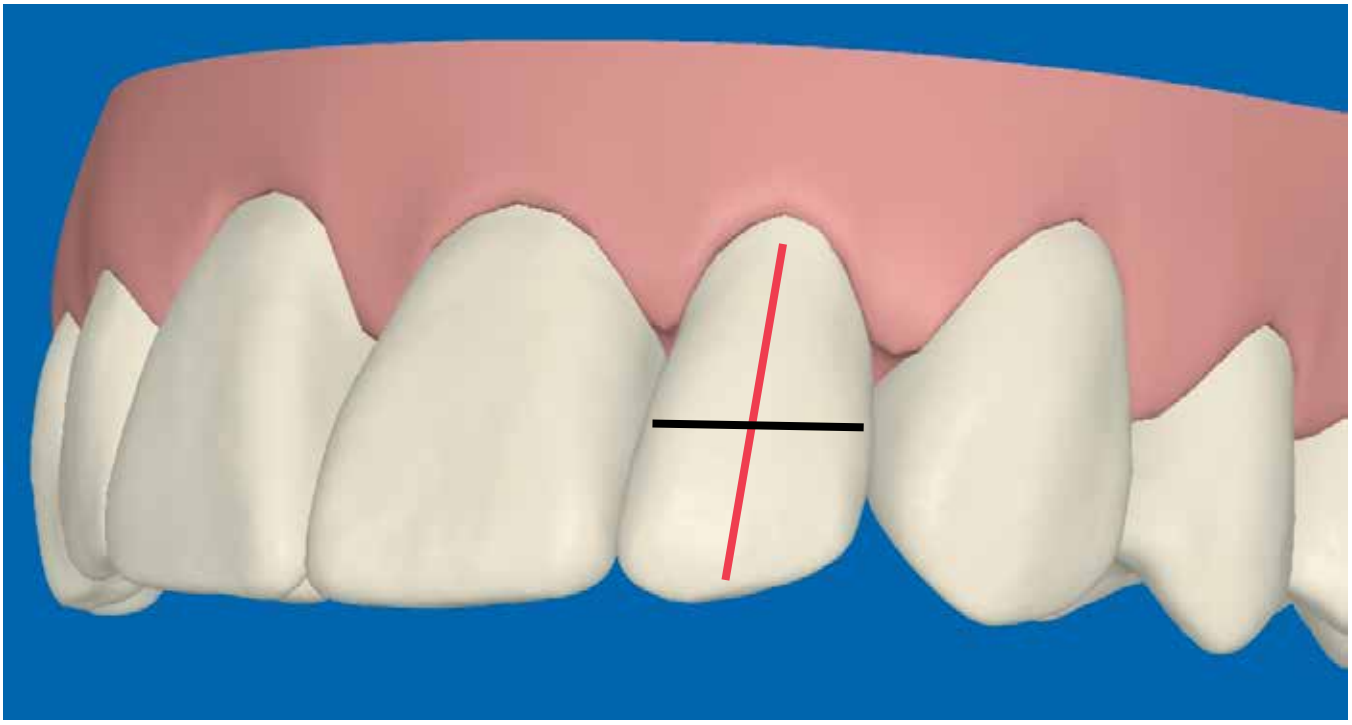

Figure 1: Compare the width of the clinical crown of the lateral versus the wider central and cuspid. Pushing on the central or cuspid at their most lateral extent of the crowns affords us a longer moment arm than doing the same of the narrow lateral. This shorter moment arm is one reason why rotating maxillary laterals is so challenging.

Tripping the Plastic Fantastic

Rotation sensation for laterals and cuspids with Invisalign

BY JONATHAN L. NICOZISIS, DMD, MS

To "trip the light fantastic" is to dance nimbly or lightly, or to move in a pattern to musical accompaniment. When correcting malocclusion and tooth positions with Invisalign, I often feel as if I am moving teeth nimbly and lightly in a certain pattern or protocol with plastic as the accompaniment.

As chapters about the history of Invisalign are continually written, what is evident is that certain movements once deemed as impossible transitioned to being challenging, and eventually were filed in the folder of predictable movements that are no longer a concern for the skilled clinician.

Using a discerning analysis of initial tooth position, more specifically root position/inclination and center of resistance in relation to the crown, doctors can design clincheck to maximize an aligner's pushing strength while negating its pulling weakness.

JONATHAN L. NICOZISIS, DMD, MS, has been practicing since 1999. He completed his dental education at the University of Pennsylvania before attending Temple University for his orthodontic residency. He is a member of the Angle Society and Invisalign® National Speaker's Bureau and Clinical Research Network. He is also the founding orthodontist and former scientific advisory board member of BAS Medical (now Corthera). Nicozisis is also on the Scientific Advisory Board of PROPEL Orthodontics.

The Challenges

Why are rotating maxillary laterals with aligners so challenging? There are three factors that contribute to this task.

First, we must consider that it may be a function of the narrow width of the clinical crown minimizing the surface area in contact with the aligner; more so the narrow width of the clinical crown in relation to the long axis and center of rotation around this long axis. Think of the ability to rotate a tooth with a twin bracket as opposed to a single-wing bracket. The closer one is to the long axis of the tooth when trying to rotate it, the more challenging it is to do so. The farther away the rotational force is from the long axis when it is applied, the longer the moment arm is and thus a lesser amount of force needs to be applied to effect the same rotation. As a result, the more efficient the rotation or moment (M = F x D) is. Again, think about twin versus single-wing brackets to rotate teeth.

Presumably, we are getting a pure moment or coupling forces with equal and opposite force vectors when pushing with an aligner. This assumes a static environment where the crown stays locked in the aligner full time. Our clinical experience

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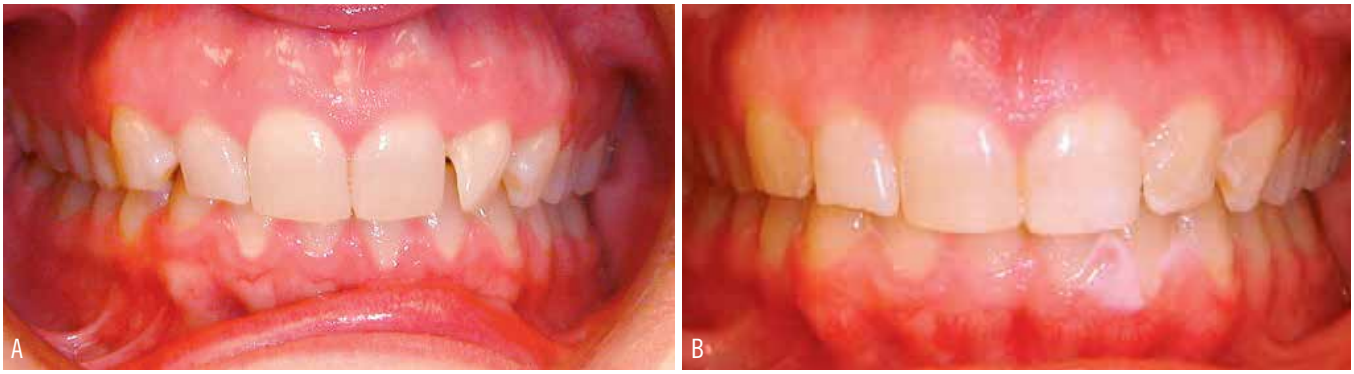

Figure 2: The tapering shape of the clinical crown from the gingival third to the incisal edge provides a lack of anatomical undercuts for the forces to "catch" onto.

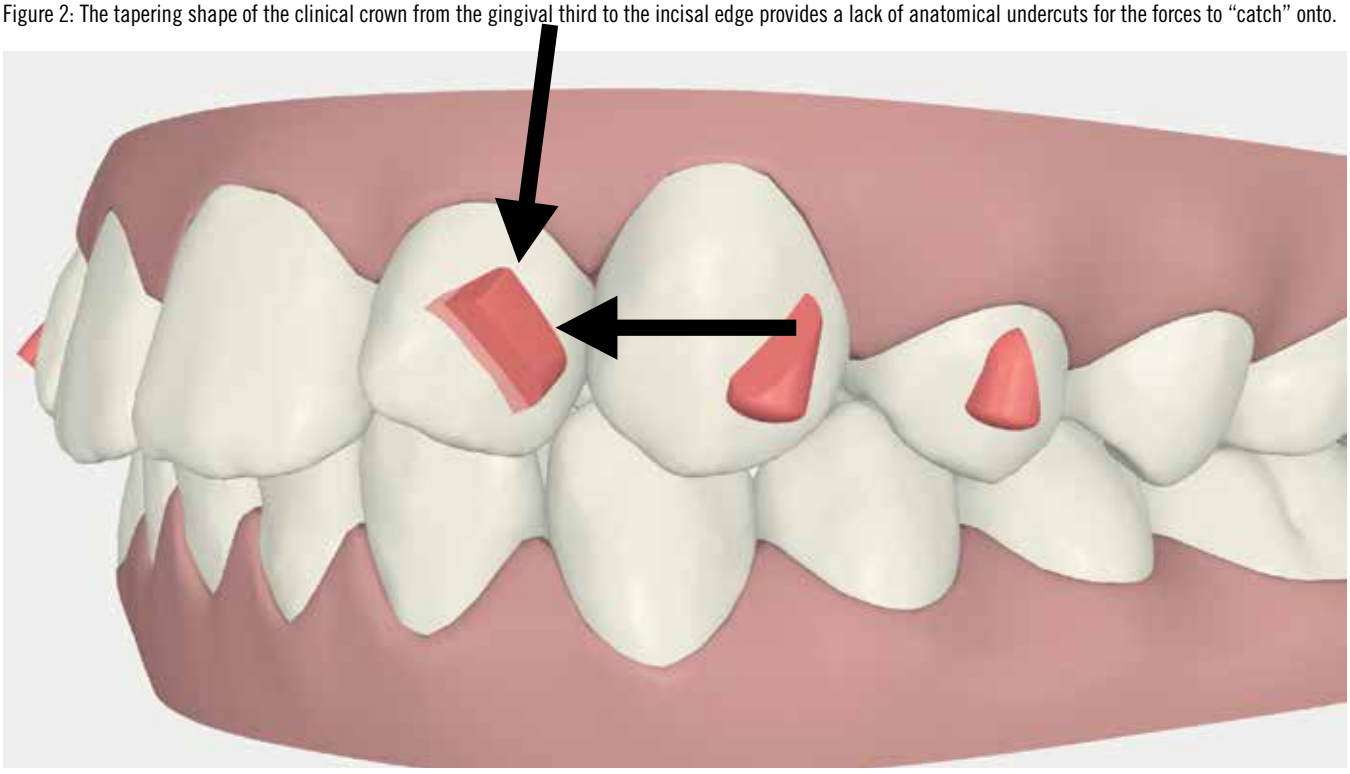

Figure 3: The beveled surface goes 45 degrees across the clinical crown, so that as the crown tapers in lingually, the attached flares out to create a broad surface to "catch" the pushing vector of force. Two vectors of force will act on the tooth simultaneously: one pushing to rotate the tooth, and the other to push the crown into the aligner.

tells us this is obviously not the case. So when we have a crown this narrow in width, the vectors of force applied to rotate the tooth are close to the long axis of the tooth, and thus we have a shorter moment arm (Figure 1, page 28).

Second, we must also consider the axial inclination of the root as another variable for what makes correcting rotated laterals so challenging. The ideal axial inclination of a Roth Rx is 8 to 10 degrees of distal root tip. As a result, the crown is not directly underneath the root apex; rather, the root and center of resistance is off axis from atop the crown that is being enveloped in plastic to effect the rotation. Gripping the bottom (crown of a tooth) of an object whose center of rotation or resistance (root of a tooth) is not directly over the top of it will be less likely to respond favorably to the rotational forces applied beneath.

Third, we have to consider the tapering shape of the clinical crown giving us a lack of anatomical undercuts to work with or to have our pushing vectors of force to "catch" onto. Without a perpendicular surface to push against, our pushing vectors of force skip off and across the clinical crown. The final result is that crowns of rotating lateral incisors do not track well in the aligner and hence are not corrected (Figure 2).

Does this mean a beveled surface should be angled 45 degrees across the crown so that as the aligner twists it will push against the attachment like threads of screw top and thus push the crown into the aligner during the rotational correction? (Figure 3) Think about the "active" surface of the cuspid rotation attachments, as I believe they address this concept. As the crown tapers in lingually in the middle/incisal third, the active surface flares out, creating this contrasting angle to the clinical crown. As the plastic twists to rotate the crown, the plastic pushes on the active surface to rotate the tooth while simultaneously pushing the crown into the aligner like twisting threads on a screw top.

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Figure 4: The use of the optimized cuspid rotation attachment for the upper right cuspid was successful since the root was directly above the crown, lacking any axial inclination.

If we create a surface that is as perpendicular as possible to the direction of our applied vector of force, and create a contrasting angle to the tapering clinical crown, (ie, the attachment flares out as the crowns tapers in), then the crown will track well in the aligner.

While Align Technology Inc has had wonderful innovation with G4 maxillary lateral attachments to accomplish "multi-plane" movements involving both extrusion along with lingual tipping or rotation at the same time, such attachments will not be applied if rotation alone is desired. Furthermore, if there is a lack of lingual tipping or extrusion occurring, these software thresholds will not be met and hence G4 lateral attachments not applied. As a result, the clinician must have other solutions available to tackle these maxillary lateral rotations.

Attachments design for rotation mesial in: Horizontal rectangular attachment 4 mm long, 1.5 mm height, 1.25 mm thick on the incisal margin tapering into the crown on the gingival margin, and rotate the whole attachment 45 degrees so it goes across the clinical crown diagonally, and as a result the distal margin is in the incisal third and the mesial margin ends in the middle third.

Attachment design for rotation distal in: Horizontal rectangular attachment 4 mm long, 1.5 mm height, 1.25 mm thick on the incisal margin tapering into the crown on the gingival margin, and rotate the whole attachment 45 degrees so it goes across the clinical crown diagonally, resulting in the mesial margin in the incisal third and the distal margin ending in the middle third.

The main difference between this diagonal attachment configuration and the G4 multi-plane attachment for laterals is surface area. This configuration has a lot more surface area that is as perpendicular as possible interacting with the aligner and pushing vectors of force. The beveled nature allows for tolerance if there is slippage between the aligner and the attachment, and will continue to push the tooth in the desired direction. Being that they are larger, it is easier to see and trim the flash as opposed to the G4 lateral attachments that are much smaller and pose difficulty when defining their edges.

The negative is that they are larger and may be cosmetically undesirable; but then again, so are braces. Nonetheless, this attachment flares out as the clinical crown tapers in, creating a contrasting angle to effectively "catch" the pushing vector of force being applied across the clinical crown to correct the rotation.

Rotation of Cuspids

When rotating a cuspid, it is of paramount importance to assess the axial inclination of the tooth. This will allow the clinician to ascertain whether the root is directly over or under the crown or if it is off axis from the crown. Clinical experience tells us that the more directly over the crown the root is, the more favorable the movement and hence the ability to use the optimized attachments routinely (Figure 4). With this vertical orientation of the root directly above the crown, the optimized attachments allow a long moment arm directed perpendicular to the clinical crown to effectively rotate the tooth around its long axis. The active surface not only pushes to rotate the tooth, but also pushes the tooth into the aligner.

If the root has an axial inclination and is not directly over or under the crown, experience proves that this is a more difficult movement and attachment adjustments must be made accordingly as the optimized attachments have proven to be less effective in these clinical situations.

For instance, if a lower cuspid crown is distally tipped while the root is mesially inclined and the crown needs to be rotated distal in, the optimized attachment will be placed in the distal incisal corner of the crown. The active surface will then have the plastic start pushing past or in front of (not behind) the center of resistance for poor directional control of its movement. Clinical experience has proven this to be a poor solution, as teeth with this initial axial inclination will not track well using the optimized attachment. It may be due to the multi-plane movement necessary to correct this cuspid's position; rotation with simultaneous distal root tip. The G4 second order attachments to correct axial inclination will not be applied either because the current software protocols allow the rotation attachment to take precedence over the second order attachments. It is my hope that this will not be the case in future generational improvements.

In these clinical scenarios, I have found it beneficial to use a long vertical rectangular beveled attachment placed on the mesial half of the crown, thicker on the mesial tapering into the crown on the distal margin (Figure 5, page 34). Such configurations provide a broad surface to push against that maximizes

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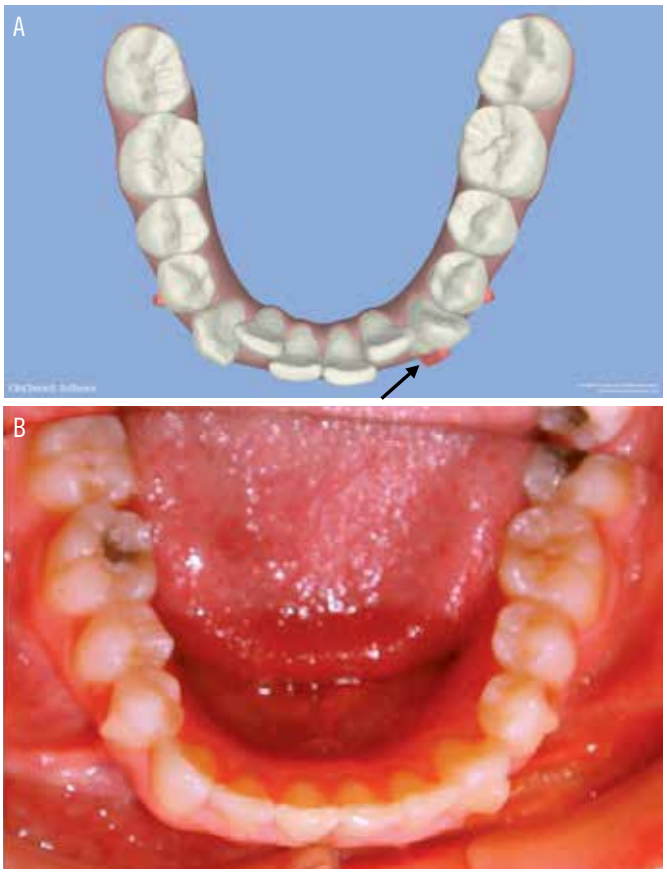

Treatment Plan

Figure 5: For cuspids that have an axial inclination of the root mesially and distal crown inclination, a vertical beveled attachment in this configuration creates a broad, perpendicular surface that is placed on the mesial half of the crown to start pushing from behind the tooth's center of resistance for better directional control of the multi-plane movement. If the default optimized rotation attachment would be used, it would be placed in the distal incisal corner of the crown; for teeth with this axial inclination, it does not provide a good pushing surface.

the surface area and is as perpendicular as possible to the pushing vectors of force. Since it is placed on the mesial half of the crown, the pushing vector of force starts pushing from behind the center of resistance for better directional control of root movement.

While the beginner or novice may "trip" over the plastic and stumble when first attempting cases with more challenging movements, taking the time to differentially diagnose initial crown and root positions will pay dividends in the end. Developing such clinical acumen will transform one's initial stumbling to "tripping the plastic fantastic," allowing you to nimbly and lightly move malpositioned teeth effortlessly and efficiently using sophisticated software, a few clicks of the mouse, and composite with plastic as the perfect accompaniment for a coda of perfectly aligned teeth as the final composition. **OP**

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