It’s generally accepted that panoramic radiographs have some inherent error in their representation of root alignment and length. Flattening any three-dimensional structure into two dimensions is going to come with such error, and is why attempts are made in other professions, such as cartography, to correct for these distortions. But in orthodontics, despite knowing the errors, we still rely largely on the pano for information about root angulation. Studies have been done to show that there is distortion when objects are outside of the focal trough. My first encounter with such information was in a study Dr. David Hatcher did as a part of an article we wrote years ago (J.C. Quintero, A.H. Trosien, D.C. Hatcher, and S. Kapila, Craniofacial imaging in Orthodontics: Historical perspective, current status and future developments. Angle Orthodontist 1999; 69(6): pp 491-506). The knowledge that 2D radiographs are inherently distorted was one of the prime motivations for the incorporation of CBCT into my practice.

While I use the 3D volume for root position within the practice, the software I use (Invivo from Anatomage) has a virtual panoramic machine that has the ability to generate a pano from the 3D volume as if it were an actual 2D machine. Using a wire representation of an arch with teeth (first molar to first molar), it is possible to qualify how alterations to the focal trough and inclinations of the teeth can affect the apparent angulations of the roots on the pano (Fig. 1).

Knowing this information is important for two reasons. For offices using 2D panos it helps to know how actual tooth inclination affects the apparent tooth angulation on the pano. For offices using CBCT, but needing to construct panos for use with referring offices and/or specialists, it helps to know how alterations in the focal trough can affect the apparent angulation of the teeth on the constructed pano. This is especially helpful for orthodontists who have staff members doing the construction and wish to provide them with guidance on how to do it.

In creating a pano within Invivo, the focal trough is set by aligning five points along the arch form (Fig. 2).
Typically the center node is put on the arch form (or on the average of the upper and lower arch forms in an actual patient) between the central incisors. The adjacent nodes should be put at the canines and the next nodes are put at the premolar/molar area. The final nodes should be placed just beyond the condyles.

If the entire focal trough is set facial to the arch form, the horizontal distance of all of the teeth is increased. In other words, the pano is widened laterally. If the entire focal trough is set lingual to the arch form, the horizontal distance of all of the teeth is decreased; i.e.: the pano is narrowed laterally. This is widely known.

Now if we look at the different dimensions we typically think of when we evaluate the teeth, we can see the effects of the shape of the trough. First, consider root angulation (angulation is mesio-distal root tipping, commonly called "tip"). This does not distort appreciably based on any variance of the focal trough from the arch form. In the wire study, if the other variables of root position are controlled (i.e.: there is no inclination) this becomes obvious. Using the aligned focal trough as a reference (Figs. 3a & b), moving a node facial (Figs. 4a & b) or lingual (Figs. 5a & b) to the arch form has no effect on the apparent angulation of the roots.

The interesting effects begin to show when root inclination is introduced (inclination is facio-lingual root tipping, commonly called "torque"). The most obvious effect of root inclination is to reduce the apparent tooth length on the pano. In the wire example, if the wire representing the upper left central incisor is inclined severely, and is long, but the right central is short but not inclined, the inclined tooth appears shorter than the un-inclined tooth (Figs. 6a & b). We know this as foreshortening.

But beyond that, interesting and less well-known effects occur as parts of the focal trough move off the actual arch form. Using Invivo, the way to move the focal trough off the arch form is to move a node. Moving a node lingual to the arch form has the effect of tipping teeth with lingually inclined roots toward the node, and facially inclined roots away from the node. For example, bringing the incisor node lingually means the teeth with the greatest inclination appear to have more mesial root tip than in reality (Figs. 7a & b).

The greater the amount of inclination there is, the greater the amount of apparent mesial root angulation. Why is that? Invivo offers the possibility to convert a pano to a flattened 3D structure. If we do that, it appears as if the mandible has been flattened such that the rami comes forward into the same coronal plane as the symphysis (Fig. 8). In other words, if we convert the pano to 3D to give it the depth of the actual bones and teeth, and then rotate the structure downward so we’re viewing it from the top of the head, we can see the view shown in Figure 8.

Now, if we take that same technique, and convert the wire arch form to a 3D pano, and then view it from above, it is clear what happens when a node is taken off of the arch form: The

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focal trough arcs out to the node, and gives the appearance that the arch form (the straight line) bows forward causing a semicircle (Figs. 9a & b).

Since it’s a circular form, anything leaning backward from the straight line is now leaning toward the center of the circle, which appears as mesial root angulation.

If we take the incisor node and move it facial to the arch form, then on the pano the teeth with lingual root inclination appear to move distally, away from the node (Figs. 10a & b).

Again, the explanation can be seen by rotating the 3D pano to view from above: The straight line (i.e.: the pano arch form) is bowed backward into a semicircle, causing the lingually inclined wires to lean to the outside of the circle (Figs. 11a & b).

Moving other nodes along the arch form has the same effect.

Because the inclination of roots means that objects (i.e.: root tips) are outside of the arch form, moving nodes can also create artifacts that are not actually present. Specifically, if we move two nodes so that they have competing effects on the apparent angulation of a root, weird things can start to appear. It’s easiest to illustrate this by showing what each node does, and then show both competing for root angulation. Taking the left canine node and moving it lingually tips the root of the left incisor distally (Figs. 12a & b).

Taking the right canine node and moving it lingually tips the root mesially (Figs. 13a & b).

If we keep the right canine node lingual, and move the left canine node lingually as well, we can see the distortion on the right and left side “pull” the root of the incisor in two different directions, stretching the root tip both mesially and distally (Figs. 14a & b).

Then, if we move the left node in further, so both canine nodes are placed substantially to the lingual, you end up with the node on the left winning the battle and pulling the root distally (since the semicircle is closest to the tooth on that side), but the right side ends up with a weird artifact where the root tip was being pulled mesially toward the right node (Figs. 15a & b).

Viewed from above, the artifact appears to be floating in the back of the arch, and the two semicircular distortions can be seen (Fig. 16).

If we instead take the left node lingually, but now move the right node facially, we don’t see any competing pull for the root.
(Figs. 17a & b). That’s because the facial movement of the node on the right bows the arch lingually, pushing the root tip to the distal, and the lingual movement of the node on the left bows the arch facially, pulling the root tip to the distal. Both have the same effect on the apparent root position of the incisor, so there is no competing pull.

To show that this effect is dependent on root inclination, if the same node movements are applied to the wire arch with no inclination there is no such artifact creation (compare Figs. 3a & b with Figs. 18a & b).

So how is any of this useful? First, it shows the value in having a three dimensional image to work from when evaluating the roots of the teeth. Additionally, for those constructing a pano from a CBCT, it illustrates how important it is to get the focal trough correct. Sometimes this is not possible, such as in a person with a severe overjet or underbite. In other cases, such as where the maxilla is particularly narrow or V-shaped, but the mandible is U-shaped, there is also no way to get the focal trough to line up ideally with both arches.

When evaluating panos from traditional pano machines, there is no option to customize the focal trough after the fact, therefore some of these distortions and artifacts should be expected. In evaluating root angulation in a person with very proclined teeth, or with teeth varying in the amount of inclination, there is not much information about root tip that can be depended on confidently. In cases like these, it might be best to not make treatment decisions involving root tip, such as bracket repositioning or detailing bends. Looking at a real-world example, a subtle change in the position of the canine nodes can drastically affect the apparent angulation of the upper and lower lateral incisors (Figs. 19a & b and Figs. 20a & b).

So, in terms of best practices, it would be advisable not to use the 2D panoramic film to judge root position; CBCT is superior in that it shows the exact position of the roots with no distortion. However, if a pano is the only film available, one should keep in mind when interpreting the film that teeth with substantial inclination (i.e.: upper anterior teeth) might show false angulation. If a pano is to be constructed from a CBCT, the adjustment nodes should be placed carefully, and on the arch form of the patient. For most arches, a node between the incisors, one over the canine areas and one over the first molar areas gives a good arch form for the focal trough. In patients where the upper and lower arch forms are quite different, a single constructed pano might not be possible, and a separate construction for each arch might be necessary. For instance, if a patient has a crossbite, the teeth in crossbite are going to require a different arch form than the teeth in the opposing arch. In Class II and Class III cases, angulation will not show as much error (since the arch forms themselves are similar, just displaced in the sagittal plane).

Author’s Bio

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