The Transverse Dimension: Diagnosis and Relevance to Functional Occlusion

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Introduction
The goals of orthodontic treatment are well established for static and functional occlusal relationships. In order to achieve Andrews’ six keys to normal occlusion for the dentition, the maxillae will relate optimally, usually due to a deficiency in the width of the maxilla, the teeth will erupt into a crossbite or reconfigure their inclinations to avoid a crossbite. This compensation typically involves lingual tipping of the mandibular posterior teeth, which are then described as being excessively positively inclined (Figure 1).

Transverse Deficiency and CR/CO Discrepancy
In the prosthodontic literature, these transverse tooth compensations have been graphically illustrated with a crossbite arch constructed through the buccal and palatal cusps of the maxillary posterior teeth. These teeth are tipped facially. These teeth are then described as being excessively positively inclined (Figure 1).
the maxillary molars. This is known as the curve of Wilson. With excessive inclination of the maxillary molars to compensate for insufficient maxillary width, the curve of Wilson is greatly exaggerated, and the palatal cusps are positioned below the buccal cusps (Figure 2).

According to McNamara and Braden,9-12 the orientation of the lingual cusps of the maxillary posterior teeth... often lie[e] below the occlusal plane... This common finding in patients with malocclusion often is due to maxillary constriction and subsequent dentoalveolar compensation in which the maxillary posterior teeth are in a slightly flared orientation.9 The results of a study by McMurphy and Scecal indicate that vertical distraction of the condyles in CR/CO discrepancies can be related to an exaggerated curve of Wilson, secondary to a transverse deficiency of the maxilla. These authors conclude that in the absence of a posterior cuspitate, the plunging palatal cusps and exaggerated curve of Wilson become the fulcrum point for the vertical condylar distraction from CR to maximum intercuspsation. Furthermore, extrapolation of this statement suggests that if the transverse skeletal dimension is normalized, the curve of Wilson is flattened and the arches are coordinated, an important component of the CR/CO discrepancy is eliminated.

Transverse Deficiency and Working/Nonworking Interferences

It has been a prosthetic maxim that an exaggerated curve of Wilson increases the potential for working and non-working side interferences. Studies have shown that posterior occlusal contacts or interferences are linked to increased masticatory muscle activity.13,14 In studies where these interferences have been removed, it has been demonstrated that the activity of the closing musculature is reduced.14,15 In addition, a study that artifically created non-working interferences reported increased muscle activity.16 These results suggest that it is prudent to normalize the transverse jaw relationship and flatten the curve of Wilson to eliminate the potential for excessive posterior interferences or contacts.

Transverse Deficiency and the Periodontium

Herberger and Vanarsdall17 have shown an increased risk for gingival recession in the orthodontic patient with a narrow maxilla when the skeletal transverse issue is camouflage with dental expansion. The envelope of treatment in the transverse, with expansion of only the dentition, is more limited than the envelope of treatment in the sagittal dimension.20 Due to the constraints of the thin layer of cortical bone of the alveolus, as shown in Figure 4 (see next page), very little tooth movement needs to occur before the roots are fenestrated, the volume of buccal alveolar bone is reduced, and, with thinning gingival tissues, the risk of gingival recession increases.

In recent studies, Harrell9 and Nunn and Harrell22,23 have shown that the elimination of working and non-working interferences enhances the long-term periodontal prognosis in patients susceptible to periodontal disease. Therefore, normalizing the transverse jaw relationship to eliminate an exaggerated curve of Wilson and nonworking interferences would be beneficial for adult patients who are periodontally at risk, and might prophylactically reduce the risk for younger patients.

Transverse Deficiency and the Airway

Ricketts’ description of “adenoid facies”24 also suggests a relationship between a constricted nasopharyngeal airway and a narrow maxilla. Ricketts states children with any impairment of the nasal passages become predominantly mouth breathers. Since the tongue is positioned in the floor of the mouth to allow airflow, it cannot provide support to shape the developing palate; thus pressure from the circumoral musculature acts unopposed. The palate is narrowed, and an exaggerated curve of Wilson develops upon tooth eruption. Because the tongue is positioned low in the mouth, the patient may also develop a retruded, high-angle mandibular shape, which can increase the risk for sleep apnea.25 An example of adenoid facies is shown in Figure 5.

In one recent study,26 patients with transverse deficiencies due to a narrow maxilla who were treated with rapid palatal expansion, showed an increase of 8% to 10% in the volume of the upper airway. In another study,27 patients with dental posterior cuspites who were treated with palatal expansion also showed an increase in the volume of the upper airway. Oliveira de Felipe, et al28 found that palatal expansion decreased nasal resistance and improved nasal breathing. While additional research in this area is certainly needed, the current literature suggests that any improvement in the volume of the airway, as an effect of palatal expansion to optimize the transverse dimension of the jaws, may greatly benefit overall growth and development.

Methods of Transverse Diagnosis

With a transverse deficiency due to a narrow maxilla, the temporo-mandibular joints, musculature, periodontal tissue, and airway can be adversely affected in the susceptible patient. Our goal as orthodontists should be to develop skeletal relationships and a functional occlusion that are as close to optimal as possible, to lessen the role that any discrepancies of the occlusion would play in exacerbating the detrimental effects to the joints, periodontium, or dentition. In order to achieve this, a correct skeletal and dental diagnosis in all three planes of space is mandatory.

In this section, we present three different methods for diagnosing the transverse dimension—one using traditional cephalometry, one using dental casts, and one using cone beam CT (computed tomography). We do not endorse any one of these methods over the others; our purpose here is simply to describe all three methods, so that readers will be able to incorporate a transverse skeletal diagnosis into their practice, no matter what level of technology is available. Regardless of which of these methods one chooses, one still must keep optimal treatment goals in mind as a rationale to normalizing the transverse dimension (Figures 6 and 7).
Ricketts' P-A Analysis

In 1969, Ricketts introduced analysis of the transverse skeletal dimension as part of his method of cephalometric diagnosis. His method uses the frontal, or posteroanterior (P-A) cephalogram, and is based on the dimensions of the jaws compared to a table of age-adjusted normative values.

One of the diagnostic criteria, Element III, is devoted to analyzing the transverse relationship of the maxilla and mandible. For the maxilla, the jugal point (Mx) is located on the right and left sides of the maxillary skeletal base at “the depth of the concavity of the lateral maxillary contours, at the junction of the maxilla and the zygomatic buttress.” The premise of the analysis is based on locating two skeletal points to determine maxillary width and two additional skeletal points to determine mandibular width (Figure 8).

For the maxilla, the jugal point (Mx) is located on the right and left sides of the maxillary skeletal base at “the depth of the concavity of the lateral maxillary contours, at the junction of the maxilla and the zygomatic buttress.” The maxillary width is determined by the horizontal distance connecting these two points. For the mandible, a similar measurement is taken between the two antegonial notches (Ag). These notches are located on the right and left sides of the mandibular body at the “intermost height of contour along the curved outline of the inferior mandibular border, below and medial to the gonial angle.”

One of the measurements has been taken, the mandibular width (Ag-Ag) is subtracted from the maxillary width (Mx-Mx) to get the difference in width between the jaws. Ricketts then determined skeletal age-determined normative relationships between the maxilla and the mandible (Figure 9). This allows the analysis to accommodate growing patients, and allows for the differential growth rates and potentials of the maxilla and the mandible.

Andrews' Element III Analysis

In 1970, L. F. Andrews published his landmark paper describing the six keys to normal static occlusion. Over the next several decades, he and his son, W. A. Andrews, worked to develop the six elements philosophy of orthodontic diagnosis. One of the diagnostic criteria, Element III, is devoted to analyzing the transverse relationship of the maxilla and mandible and is based on both bony and dental landmarks. The Element III analysis is based on the assumption that the WALA ridge is coincident with the most prominent portion of the buccal alveolar bone, when viewed from the occlusal surface (Figure 11).

The WALA ridge is essentially coincident with the maxillary FA point of the right and left molars. In a mature patient, the WALA ridge and the width of the mandible cannot be modified with conventional treatment. Thus the WALA ridge forms a stable basis for the Element III analysis.

The Element III analysis is based on the width change, if any, of the maxilla needed to have upper and lower posterior teeth upright in bone, centered in bone, and properly intercupperated. To determine the discrepancy, the first step is to determine the width of the mandible, the horizontal distance from the FA point of the left molar to the FA point of the right molar and records the measurement.

The result represents the width of the maxilla. In order to have optimally positioned and optimally inclined molar teeth that intercupperate well, Andrews states that the maxillary width must be 5 mm greater than the mandibular width. In order to determine the amount of transverse discrepancy, or Element III change, needed to produce an ideal result, one takes the optimal mandibular width, adds 5 mm, and subtracts the width of the maxilla. The ENTREPI sults of the maxilla and the mandible.

The width of the maxilla is based on optimization of the angulation of the maxillary molars. To determine this width, one measures the horizontal distance from the FA point of the left molar to the FA point of the right molar and records the measurement.

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To determine the width of the mandible, we scroll down through the MPV screen to see simultaneous axial, sagittal, and coronal views. After properly orienting the image, we open the multiplanar view (MPV) screen to see simultaneous axial, sagittal, and coronal views. Using the cut lines as a guide, we measure the width of the mandible from the intersection of the cut line with the most buccal portion of the cortical plate on both the right and left sides.

Thus, to locate the beginning of the base of the mandible with a CT scan, it would seem best to find the skeletal representation of the WALA ridge. This is approximately at the edge of the cortical bone opposite the furcation of the mandibular first molars. We can also use this technique to locate the beginning of the base of the maxilla. If we assume that the maxilla begins at the projection of the center of resistance of the maxillary teeth onto the buccal surface of the cortical bone, Ricketts’ use of Mx point to determine maxillary width appears to be at approximately at the same horizontal position. Additionally, by using Mx point, any exostoses present along the buccal portion of the alveolus will not interfere with the measurement. Andrews’ method, on the other hand, has no directly definable skeletal landmark for the maxilla; it relies on estimated changes in the angulation of the molars to determine the skeletal transverse discrepancy. Therefore, Ricketts’ method of defining the basal skeletal width of the maxilla appears to be more appropriate.

We begin, then, by defining locations for measuring maxillary and mandibular basal width. First, we explore concepts for defining these locations on cone-beam CT imaging. The basic premise for the mandible is to locate the most buccal point on the cortical plate opposite the mandibular first molars at the level of the center of resistance. According to Katona, this location is approximately coincident with the furcation of the roots of the molars.10 As we explained above, the authors chose this point due to the relative immutability of the alveolus apical to this location with orthodontics and because it represents the absolute minimal width of the basal bone for each jaw.

For the purposes of this technique, the authors used Dolphin 3D, release 11, but the concepts can be applied to any software with the capability to analyze a cone-beam CT image. After properly orienting the image, we open the multiplanar view (MPV) screen to see simultaneous axial, sagittal, and coronal cuts of the image.
mandibular width from the maxillary width, we determine the difference between the two jaws. Both Ricketts’ and Andrews’ analyses demonstrate that the optimal transverse difference between the maxilla and mandible is 5 mm in mature patients. A preliminary analysis of 5 cases where the maxillary and mandibular molar were upright in the alveolus, and well intercuspated produced measurements where the difference between the width of the jaws approximated 5 mm on a consistent basis. Therefore, the seemingly ideal difference for the width of the jaws in mature patients using the Penn CBCT analysis would also appear to be 5 mm. To determine the amount of expansion necessary to achieve an ideal jaw relationship in the transverse dimension, the measured difference between the jaws should be subtracted from 5.

Figure 21: Example of optimal transverse skeletal relationships using cone-beam CT analysis.

Research performed by Simontacchi-Gbologah, et al., has verified the validity of the University of Pennsylvania CBCT analysis for the transverse diagnosis. However, the difference between the described method here and the method in the aforementioned research is that the measurements were taken on coronal cuts, not axial ones. Due to the cross section of the mandibular coronal cut being taken at an angle that is not perpendicular to the alveolus, a false perception of the thickness of cortical bone is possible, as shown in Figure 22. Therefore, to reduce errors in judgment and to improve visualization of the most buccal portion of the cortical bone, the authors believe that the axial cut allows for greater precision of measurement over the coronal cross section.

Figure 22: Visualization of cortical bone thickness in coronal and axial cuts of the same patient.

References

For complete contributor information, please see next page.
Hinge Axis: The Need for Accuracy in Precision Mounting

Summary
This is the second part of a two-part paper discussing the need for accuracy in the mounting of dental models for orthodontic diagnosis and treatment. Part 1 discussed the accuracy differences between an arbitrary hinge axis (AHA) mounting and a true hinge axis (THA) mounting. Part 2 discusses the differences between two popular true hinge axis recording devices, the Panadent Axi-Path system and the Axiograph III system.

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The Axi-Path System
Many clinicians use the Panadent Axi-Path system for the following purposes: (Figure 17)
- To locate the true hinge axis (THA)
- To determine the sagittal anterior condylar path inclination, non-working-side sagittal lateral condylar path inclination, and the Bennett movement to select the Motion Analog Blocks
- To assess the functional structural conditions of the temporomandibular joint

Figure 17 Axi-Path recording, Panadent Company.

The upper head frame of the Axi-Path recorder is composed of two symmetrical arms that move around a hinge joint at the center of the frame (Figure 18). The upper frame is fitted and fastened to the head by tightening the hinge with a thumbscrew. A straight ruler can be used to make the two flag tables parallel to each other. (Figure 19).