The Human Face as a 3-Dimensional Model: The Future in Orthodontics

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Editor's Note: *Sam Weinstein, a great American orthodontist and teacher, once said, "Anybody looking at our radiographic diagnostic measurements would think we are a generation of profiles." He had in mind our preoccupation with the "numbers racket," as he called the myriad numbers of angles, lines, and percentages, based on 2-dimensional lateral cephalometric radiographs. It is hard to believe that it is the 70th anniversary of the first article on radiographic cephalometric assessment by the eminent B. Holly Broadbent. He made it a point to stress the use of both lateral and anteroposterior (frontal) radiographs to determine craniofacial and dental relations, but his pleas were largely ignored. We continue to "count the number of angels on the head of a pin," devising new measurements each year for lateral cephalometric tracings. Amazingly, even with the widespread use of rapid maxillary expansion procedures, preoccupation with the lateral ceph continues. Dr Weinstein did his master's degree research on the use of the frontal radiographic ceph and must be pleased to see belated recognition of his plea to consider the transverse, the third dimension in our diagnosis, before, during, and after treatment in this landmark article. Hopefully, it will stimulate routine 3-dimensional perusal of patients, not only for treatment, but for studying growth and development and long-term stability of treatment results.* —T.M. Graber

This is a new approach in orthodontic treatment and orthognathic surgery. It follows the concept of individualized balance for each face, balance that is the result of either natural harmonious growth and/or appropriate therapy. The method, using C2000 Cepha (Cirad, Montpellier, France) software, combines computed tomography (CT) data, anatomic landmarks, and mathematic tools to create a 3-dimensional model of the human face. This new individualized balance recognizes the unique combination of morphogenetic factors. We can appreciate volumes and forms, the bone limit of the denture, and the symmetry or asymmetry of the mandible.

The balance and symmetry of this computer model are stable enough to define normality for each individual, regardless of the patient's ethnic and cultural origins. Asymmetry characterizes pathologies. Follow-up models allow easy and accessible growth prediction and modeling. This avant garde method is in the process of becoming the indispensable reference for all those interested in studying the human face.

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3-DIMENSIONAL IMAGERY OF THE HUMAN FACE

From the CT data, the C2000 software creates 3-dimensional imagery using the threshold method and the principle of the dividing cube[1]; these define areas of isovalues in a volume. In this way, the anatomic maxillofacial elements are reconstructed: the teeth, bones, skin, and muscle. Computer tools can then be used to isolate and/or mix these elements, with more or less transparency and depth, in relationship to each other. Using a single CT scan, it is possible to realize a multitude of views in the 3-dimensional reconstructions.

3-Dimensional model of the human face

Using the x, y, and z values of eight anatomic landmarks selected on the original axial CT scan (both mental foramina, both infraorbital foramina, both supraorbital foramina, and the heads of both mallei), the software creates a geometric construction called “the maxillofacial frame.”[2,3] The maxillofacial frame is two pentahedrons, opposed by a common trapezoidal horizontal area, delimited by both infraorbital foramina and the head of both mallei. This horizontal area is basically flat and is perpendicular to a vertical facial area delimited by both supraorbital foramina and both mental foramina. This facial area is also basically flat, and it contains both infraorbital foramina.

It is possible to calculate 168 angular values, 28 distances, and 64 areas. These are true values and not the measurement of parameters projected on a flat plane, as in conventional cephalometry. Two volumes, orbital and intermaxillary, may also be calculated.

An avant garde feature of this method is that the C2000 software calculates a new 3-dimensional cephalometric parameter called “the axes of inertia” for each tooth or tooth group.[4,5] This parameter is created by using selections on the original axial CT scan of teeth.

An object of any form has three axes of inertia that are perpendicular to each other. These axes, which are characteristic of the geometry of the object, define a trihedron: the principal axis is the longest; the secondary is the second longest; the tertiary is the shortest. Their intersection is the center of gravity of the object. For each object, a tooth or tooth group, the calculation of the axes of inertia define a 3-dimensional landmark.

The principal axis of inertia of a tooth is the same as the coronoradicular axis. The calculation of the axes of inertia for a tooth group allows the mathematic definition of the half arches, the maxillary arch, the mandibular arch, and both arches together.

The use of the axes of inertia as a 3-dimensional cephalometric parameter allows the orthodontist to create a series of anatomic levels: the teeth, the half arches, the arches, both arches, and the maxillofacial frame. It also allows the calculation of the orientation of these elements in relationship to each other.

For Class I cases, the plane defined by the axes of inertia of both arches is parallel with the maxillary and mandibular planes and is near or the same as the occlusal plane. In Class II or III malocclusions, this plane becomes slanted. These three planes, which are parallel in a well-balanced face, are in the maxillofacial frame parallel with the horizontal plane, as defined by both infraorbital formina and the head of both mallei.

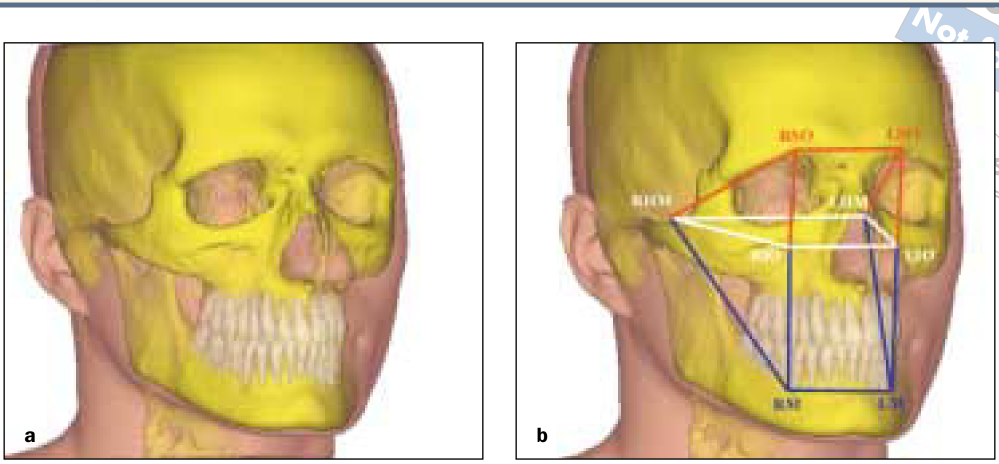
The axes of inertia of the half arches are symmetric with each other in their own arch reference. The intermediary axis of inertia, which is the anteroposterior reference of each arch, crosses between the central incisor teeth.

The mandibular principal axis of inertia crosses the first permanent molars. This means that the tooth volume in front of the axis is the same as the tooth volume behind the axis. The maxillary principal transversal axis of inertia crosses between the first permanent molars and the second premolar.

3-Dimensional model of the human face is a hierarchy of anatomic elements

The model is anatomically coherent: the eight landmarks and the teeth are located on the trigeminal neuromatricial facial growth directions described by Moss et al.[6–8] The model is mathematically coherent: all elements of the hierarchy are defined by their axes of inertia. In addition, the axes of inertia create a 3-dimensional landmark for each element that allows calculation of the orientation of each element in relationship to the others (Fig 1).

The details of this analysis support the central conclusion that the face has a natural balance. Balance is considered natural form and norm. The criteria for orthodontic treatment could be balance. How the notion of balance is used in the field of orthodontics must be determined by experience, because the notion of balance needs to integrate the demands of esthetics. It may not always be possible to reconcile balance and esthetics, which may help explain some relapse.



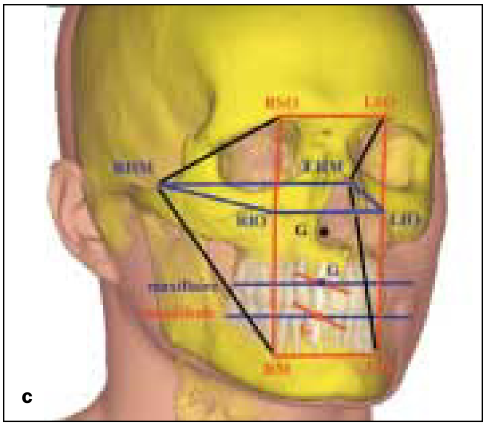


Fig 1 **(a)** 3-dimensional imagery. **(b)** The maxillofacial frame: two pentahedrons opposed by a common horizontal area. **(c)** Axes of inertia of maxillary arch and mandibular arch. At both levels: in blue is the principal axis, which is transversal; in red is the second longest axis, which is ventrodorsal; in white is the shortest axis, which is vertical. G (blue): Center of gravity of the maxillary arch. G (red): Center of gravity of the mandibular arch.

Normality. Normality combines symmetry and balance.[9–11]

Symmetry. *(1) The maxillofacial frame* (Fig 2) is composed of three surfaces: the vertical facial area (red), the horizontal basal area (blue), and the midsagittal area (green). The midsagittal area intersects the four medial points, calculated between the eight anatomic landmarks. The analysis of the maxillofacial frame considers the right/left symmetry of the verticofacial area and the horizontal basal area in relationship with the midsagittal area.

(2) Arches. There should be symmetry of the axes of inertia of the right and left half arches in relationship with the axes of inertia of the maxillary arch and the mandibular arch. There should be vertical symmetry of the axes of inertia of the maxillary and mandibular arches in relationship with the axes of inertia of both arches together.

(3) Teeth. There should be identical value for the torque and tipping angles of the corresponding right and left teeth. The projection of the principal axis of inertia of the tooth on the planes perpendicular and tangential to the dental curve allows the calculation of the torque and tipping angular values for each tooth. (Using the coordinates of the center of gravity for each tooth, the C2000 software calculates each regressive maxillary and mandibular arch curve.)

Balance. In the maxillofacial frame, the location of the center of gravity is in the midsagittal area. With the arches, frontal, sagittal, and axial projections on the same vertical axis of the maxillary and mandibular centers of gravity are created. Finally,

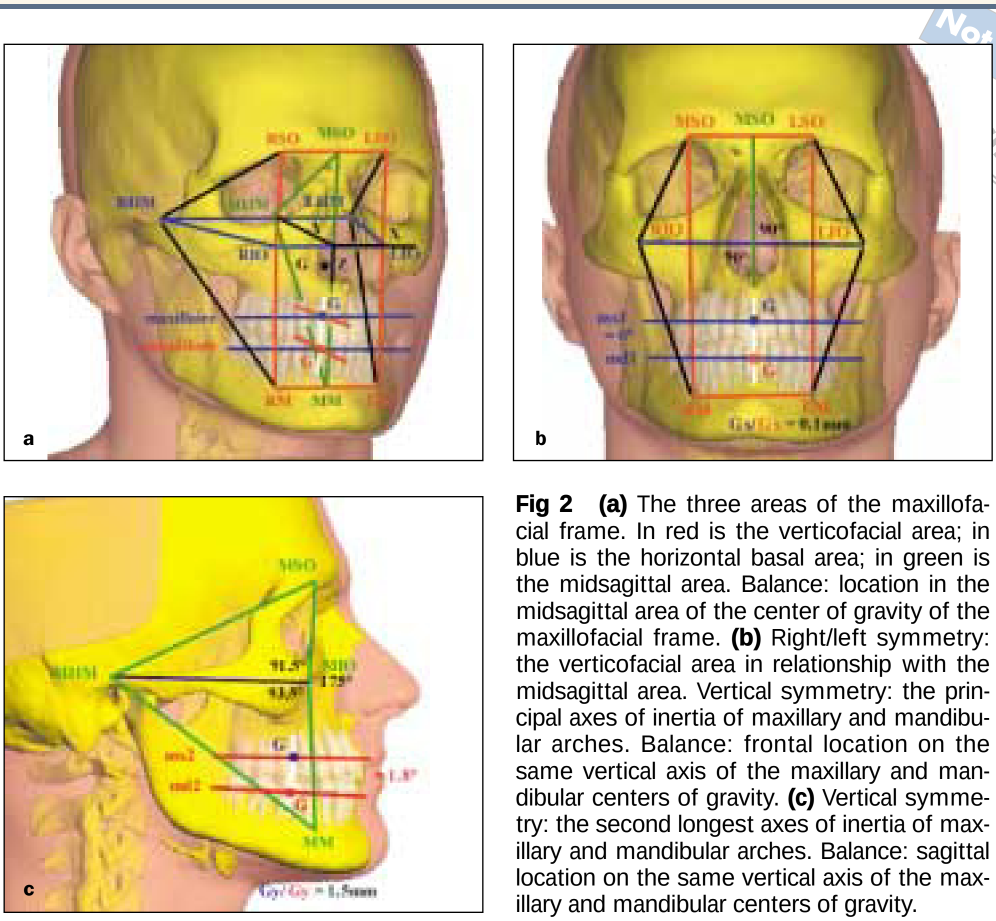


Fig 2 **(a)** The three areas of the maxillofacial frame. In red is the verticofacial area; in blue is the horizontal basal area; in green is the midsagittal area. Balance: location in the midsagittal area of the center of gravity of the maxillofacial frame. **(b)** Right/left symmetry: the verticofacial area in relationship with the midsagittal area. Vertical symmetry: the principal axes of inertia of maxillary and mandibular arches. Balance: frontal location on the same vertical axis of the maxillary and mandibular centers of gravity. **(c)** Vertical symmetry: the second longest axes of inertia of maxillary and mandibular arches. Balance: sagittal location on the same vertical axis of the maxillary and mandibular centers of gravity.

the maxillofacial frame and arch relationship is defined by parallelism between the maxillofacial frame planes and the planes defined by the axes of inertia of the arches.

Pathologies. Asymmetry and unbalance characterize pathologies.[12]

Figure 3 demonstrates the software analysis of a strong Class III malocclusion. This 3-dimensional model demonstrates, with several parameters among additional available parameters, that conventional 2-dimensional cephalometric analysis is inadequate and limited in establishing the treatment plan and strategy for the orthodontist and the surgeon.

CONCLUSION

Delaire[13] said, “Plane geometry is inadequate to analyse a volume and its growth.” This 3-dimensional cephalometry bridges that gap. These concepts of individualized symmetry and balance are demonstrated by this cephalometric analysis, with the use of CT data, anatomic landmarks, and the axes of inertia. These concepts of symmetry and balance must replace the conventional notion of normality based on mean angular values, because symmetry and balance are the real measures and appreciation of natural growth.

In addition, the 3-dimensional model is stable during growth. The authors agree with Enlow’s[14] statement that “growth is a continuous state of balance.”

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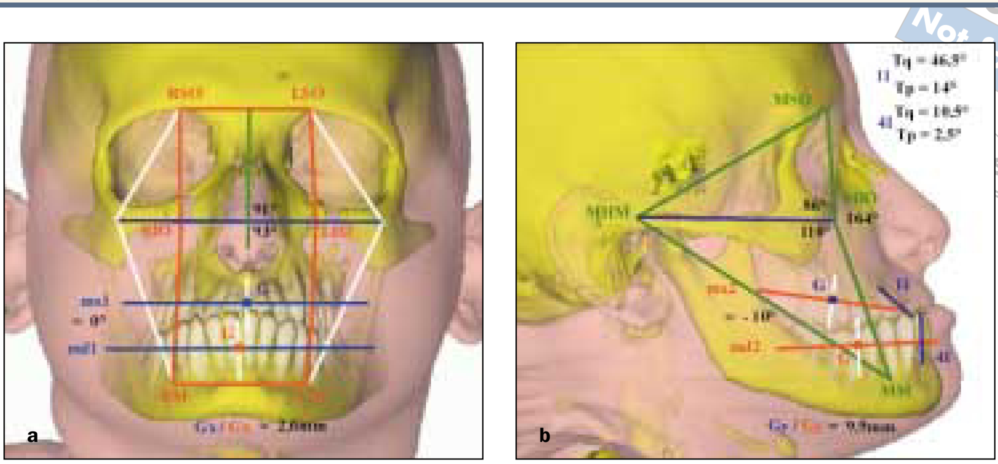
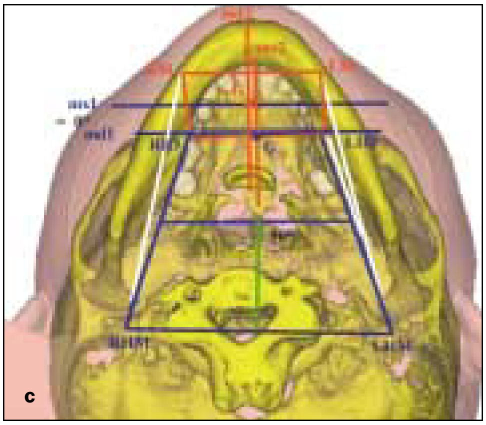


Fig 3 **(a)** Small right mandibular shift: Frontal projection shift of maxillary and mandibular centers of gravity is 2.6 mm. **(b)** Strong Class III concavity of the verticofacial area is 164 degrees. The maxillary arch is slanted: Posterior opening angle between the second longest axes of inertia of the arches is 10 degrees. Sagittal projection shift of maxillary and mandibular centers of gravity centers is 9.9 mm. **(c)** The mandibular shift is a pure strong anterior and small right lateral translation, without any rotation.



REFERENCES

1. Borianne PH, Jaeger M. Polygonisation réversible en imagerie médicale, application à la visualisation des divers tissus anatomiques, 3em colloque Africain sur la recherche informatique. Cari: Libreville, 1996:114–123.
2. Treil J, Casteigt J, Jaeger M, Cavezian R. La charpente maxillo-mandibulaire: nouvelle approche cranio-facio-métrique tridimensionnelle. Actual Odontostomatol 1993;188:627–637.
3. Treil J, Madrid C, Jaeger M, Casteigt J, Borianne P. Biométrie tridimensionnel maxillo-faciale. Cah Anthropol Biom Hum 1997;15(1–2):65–73.
4. Benzecri JP, Benzecri P. Axes d'inertie et A.C.P. Pratique de l'analyse des données. Analyse Des correspondances. Exposé élèmentaire. Paris: Dunod, 1980:20–61.
5. Treil J, Casteigt J, Madrid C, Borianne P. Une nouvelle construction céphalométrique tridimensionnelle. Un nouveau paramétrage d'analyse tridimensionnel: Les axes d'inertie. Un nouveau concept de l'équilibre maxillo-facial. Orthod Fr 1997;68:171–181.
6. Moss ML, Rankow RM. The role of the functional matrix in facial growth. Angle Orthod 1968:38:95–102.
7. Moss ML, Salentijn L. The primary role of the functional matrix in facial growth. Angle Orthod 1969;55:566–574.
8. Behrents RG, Johnston LE. The influence of trigeminal nerve on facial growth and development. Am J Orthod 1984;85: 199–206.
9. Treil J, Casteigt J, Borianne PH, Madrid C, Jaeger M, de Bonnecaze PH. L'équilibre architectural de la face: Un concept céphalométrique 3D. Rev Stomatol Chir Maxillofac 1999;100(3):111–122
10. Treil J, Casteigt J, Faure J, Borianne P. 3D cephalometry principles and method. J de l' edgewise 2000;41:69–86.
11. Treil J, Casteigt J, Borianne P, Faure J. Céphalométrie 3D: Une nouvelle définition de la normalité-Une nouvelle caractérisation des pathologies. Radiologie J Cepur 2001;21(1):25–33.
12. Treil J, Casteigt J, Faure J, Madrid C, Borianne P, Jaeger M. Architecture crânio-facio-maxillo-dentaire. Un modèle tridimensionnel. Application en clinique orthodontique et chirurgie orthognatique. Paris: Encyclopedie Medico-Chirugicale Odontologie/Stomatologie, 23-455-E-40, 2000, 8pp.
13. Delaire J. L'équilibre architectural en chirurgie maxillo-faciale en orthopédie dento-faciale et en chirurgie orthognatique. Orthod Fr 1985;56:353–364.
14. Enlow DH. Facial Growth. Philadelphia: Saunders, 1990: 232–248.