Original Article

The G-Axis: A Growth Vector for the Mandible

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Abstract: On the basis of the G-point, defined as the center of the largest circle that is tangent to the internal inferior, anterior, and lingual surfaces of the mandibular symphysis in the sagittal view, a growth axis and its direction are described for each gender from age six to 19.25 years. Incremental growth along the G-Axis, defined by Sella-G–point, is described by regression formulas with correlation coefficients of 0.673 for female subjects and 0.749 for male subjects. The vector (direction) of the growth axis, defined by the angle α {(G-Axis)–(S-N)} does not materially alter in the age range studied. At age six in female subjects the angle α is $67.16° \pm 3.03°$ and at age 19.25 it is $66.87° \pm 3.03°$, whereas in male subjects it is $66.12° \pm 4.00°$ and $67.93° \pm 4.00°$, respectively. These changes and gender differences are not clinically significant. The data is based on 444 serial lateral cephalograms of 24 female subjects and 24 male subjects. The G-Axis incremental growth change and its vector offer an improved means of quantifying complex mandibular growth in the sagittal plane by using cephalometric measurements relative to and correlated with other craniofacial structures. (*Angle Orthod* 2004;74:328–331.)

Key Words: G-Axis; G-point; Mandibular growth vector; Mandibular growth increment

INTRODUCTION

A growth vector, the C-Axis, has recently been described for the dentomaxillary complex[1] (Figure 1). Whereas a complicated process of remodeling maintains the general shape and proportions of the dentomaxillary complex, a geometrically defined point within it permits the description of the natural loci of this complex in relation to other craniofacial structures during growth and development.[1,2] Growth of the mandible is also expressed through complex changes of apposition and resorption at numerous periosteal and endosteal surfaces, the replacement of cartilage by bone at the condyle and dental eruption accompanied by growth of alveolar bone.[3] The net result is the general observation that the final effect is a downward and forward displacement of the mandible.[4,5] This has been previously quantified to a degree through the description of the Y-Axis (S-Gn).[6–9] It is noted that the usefulness of the Y-Axis has been questioned because of extensive remodeling of the external symphyseal area.[10,11]

A study was undertaken to establish an improved descriptive growth axis for the mandible, herein defined as the G-Axis. The length of this axis is determined by Sella (S) superiorly and G-point inferiorly. The G-point is defined as a point representing the center of the largest circle that is tangent to the internal inferior, anterior, and posterior surfaces of the mandibular symphyseal region as seen on a lateral cephalogram (Figure 2). The G-Axis vector (direction) is defined by the angle alpha (α), which the G-Axis establishes relative to Sella-Nasion (S-N). The mandibular plane (M), a line drawn tangent to the inferior border of the mandible through Menton relative to the S-G point, is established and defined as the angle theta (θ). Use of these three dimensions (α, θ, and the length of the G-Axis) provides a quantitative description of the anterior and downward migration of the mandible related to growth and maturation (Figure 3).

METHODS AND MATERIALS

Annual serial lateral cephalograms of 24 Caucasian male subjects and 24 Caucasian female subjects from six to 19.25 years, represented in 444 individual cephalograms, were selected from the Mooseheart Growth Study, Chicago, Ill. The subjects were chosen on the basis of acceptable quality radiographs with the subjects' head oriented to Frankfort horizontal, displaying a clinically acceptable Class I occlusion as viewed on corresponding dental models, teeth in full occlusion, no absent teeth except through normal exfoliation and no history of orthodontic intervention. The subjects were selected further on the basis that the ANB angle measurement fell within the range of one to five de-

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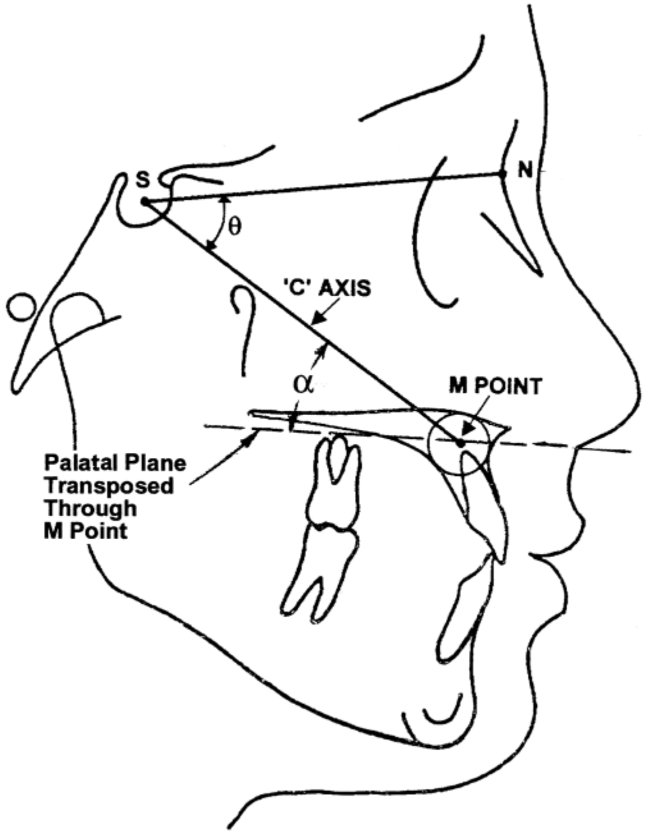


FIGURE 1. The C-Axis: the growth vector for the dentomaxillary complex.

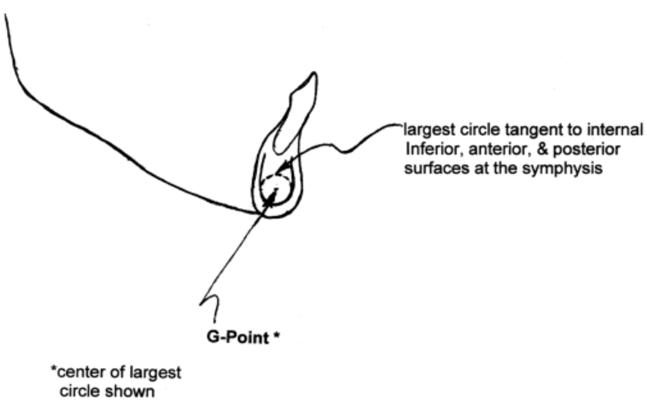


FIGURE 2. Sagittal mandibular view illustrating G-point.

grees, and the ratio of N-ANS to ANS-Gn was 0.80 ± 0.09 for male subjects and 0.82 ± 0.08 for female subjects.[12]

Cephalometric landmarks were identified on each lateral cephalogram and marked on overlaid acetate tracing paper. All angular and linear measurements were made by one person. Fifty-five cephalograms were randomly chosen from the sample of 444 radiographs, and the pertinent points and planes as defined above were remeasured to evaluate examiner error. The variation in measurements was determined to be no greater than 0.07%.

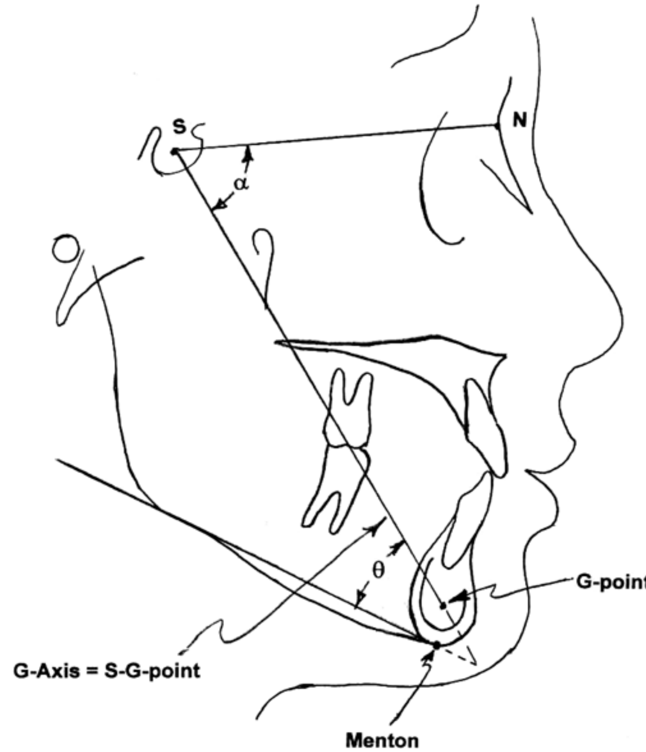


FIGURE 3. The relationship of the G-Axis (S-G point) to Sella-Nasion (S-N) and to mandibular plane (M).

The G-point was established using a specially designed transparent template containing a number of circles whose diameter increased in 1-mm increments. Each of the centers was identified by a pinhole in the template. The center of the best-fit circle tangent to the internal inferior, anterior, and posterior surfaces of the mandibular symphyseal area in each sagittal cephalogram was determined. The identified circle center was then transferred through the pinhole for subsequent measurement. The line from Sella (S) to G-point is defined as the G-Axis length in millimeters. Because the original Mooseheart Growth Study radiographs were taken at differing subject-to-film distances, the films in this study were normalized to a 90-mm midsagittal plane-film distance using the formula:

Corrected measurement value = 0.065[90 − (midsagittal plane film distance)] + measurement value.

RESULTS

The mean G-Axis linear measurements (S-G point) and mean angular values ({S-N}–{S-G point}) and ({M plane}–{S-G point}) obtained for each gender are shown graphically in Figures 4–6. All the data are not heteroscedastic; therefore, the standard deviations shown in each of the figures are valid throughout the age range shown.

DISCUSSION

The G-Axis length (S-G point) in female subjects increases linearly at a rate of 1.6 mm per year and linearly

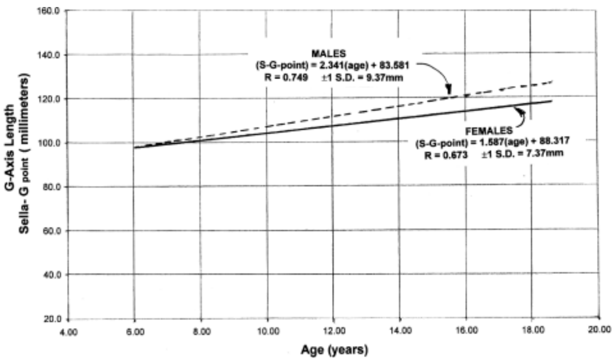


FIGURE 4. Chronologic growth along the G-Axis.

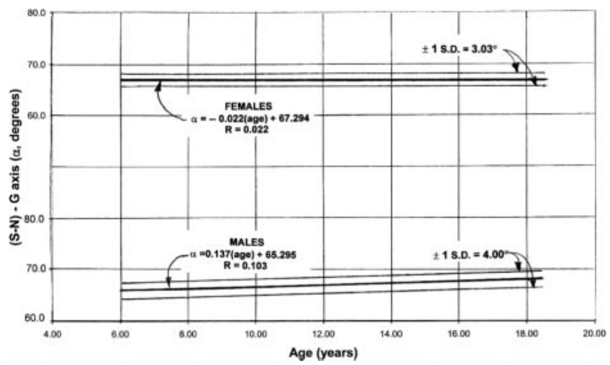


FIGURE 5. Growth axis vector angle (G-Axis–{S-N}) related to chronologic age.

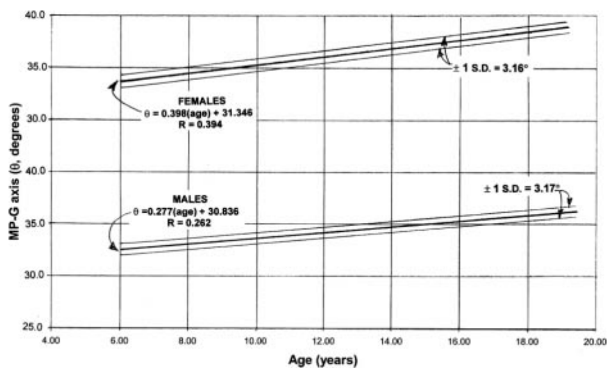
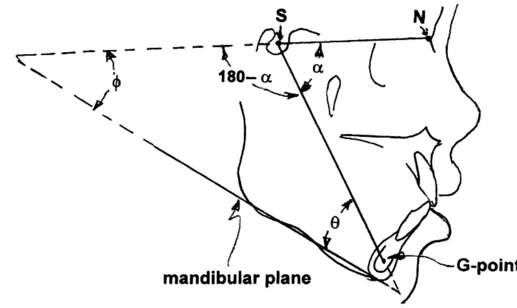


FIGURE 6. Angular relationship of mandibular plane to the G-Axis related to chronologic age.

in male subjects at a rate of 2.3 mm per year from six through 19.25 years. The growth velocities of the G-Axis length are determined by the slope of the mean linear regression formulas for each gender seen in Figure 4. At six years, the mean G-Axis lengths of the female and male subjects are 97.8 and 97.6 mm, respectively, representing no significant difference. At 6.28 years, the mean G-Axis lengths are equal for both genders. At 19.25 years, the mean male subject G-Axis length exceeds that of the female subjects by 9.8 mm. It is interesting to note that the mean velocity of G-Axis length increase for both genders is relatively constant within the age range studied.



$$\phi + (180 - \alpha) + \theta = 180$$
$$\therefore \phi = \alpha - \theta$$

FIGURE 7. Geometric relationship between the vector angles α, θ, and the angle ϕ; the mandibular plane makes with S-N.

The mean growth axis vector angle α decreases 0.02°/year in female subjects and increases 0.14°/year in male subjects. At six years, the female subject mean growth vector angle exceeds that of the males' by only 1° (67.16°–66.12°), and at 19.25 years the male subject mean growth vector angle exceeds that of the female subjects by only 1° (67.93°–66.87°). The small angular differences between genders are not clinically significant. The low correlation coefficients ($R = 0.022$ for female subjects, $R = 0.103$ for male subjects) between the growth axis vector angle (α) and age for the age range studied imply little change of the magnitude of the mean growth axis angle related to age. The slopes of both graphs are relatively shallow (Figure 5).

The mean mandibular plane angle relative to the G-Axis (θ) increases at a rate of 0.4° per year and 0.3° per year in the female and male subject groups, respectively, in the age range studied (Figure 6). Thus, from age six to 19.25 years, θ increases 5.3° (39.0°–33.7°) in female subjects and 3.7° (36.2°–32.5°) in male subjects.

It is important to recall that all the data are based on serial annual cephalometric measurements of homogeneous female and male subjects exhibiting ANB angular measurements within the range of 1°–5°, with the ratio of N-ANS to ANS-Gn = 0.80 ± 0.09 for male subjects and = 0.82 ± for female subjects. These factors represent clinically acceptable facial proportions.[12]

From a clinical viewpoint, the mandibular plane angle is commonly measured relative to S-N. This angle, herein referred to as the angle ϕ, bears a geometric relationship to the angles α and θ. It is $\phi = (\alpha - \theta)$ (Figure 7). Thus a formula relating ϕ to chronologic age for each gender may be derived from the data as follows:

$$\theta(\text{females}) = 0.398(\text{age}) + 31.346$$
$$\alpha(\text{females}) = -0.022(\text{age}) + 67.294$$

because $\phi = \alpha - \theta$, ϕ (female subjects) = −0.420 (age)

+ 35.948, and similarly for male subjects, $\phi = -0.140$ (age) + 34.459.

Consequently, the data of this study reveals the angle ϕ (mandibular plane directly related to S-N) for female and male subjects at age six to be 33.4° and 33.6°, respectively and at age 19.25 to be 27.9° and 31.8°, respectively. From the equations above for ϕ, one can see that in female and male subjects this angle decreases at an annual rate of 0.42° and 0.14°, respectively. The Atlas of Craniofacial Growth[9] for this same angle is reported as 36.5° ± 5.7° and 35.4° ± 4° for female and male subjects, respectively, at age 6. Because the Growth Atlas data is not available beyond age 16, a computation at this age using the same formulas yields a ϕ angle of 29.3° and 32.2° for female and male subjects, respectively. The Atlas lists 31.2° ± 3° and 32.9° ± 5.2° for female and male subjects, respectively, at age 16. Both the data found in the Atlas and the data obtained in this study show a generalized decrease in the mandibular plane angle relative to S-N during growth, and the mean angle ϕ found in this study falls within one standard deviation of the Growth Atlas data. This tends to validate the G-Axis as a reasonable growth vector for the mandible.

CONCLUSION

The G-Axis (S-G point) allows for the quantification of the complex mandibular growth process in cephalometric terms relative to various craniofacial structures in the sagittal plane. This has been achieved for ages six through 19.25 years for each sex.

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