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Validity of Identification of Gonion and Antegonion in Frontal Cephalograms

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ABSTRACT

This study was designed to develop a method of transferring gonion from lateral to frontal cephalograms, and to use this method as gold standard when evaluating observer performance in identifying gonion in frontal cephalograms. Observer ability to identify antegonion was also evaluated. There was a range of 28 mm in the observers' identification of gonion and a statistically significant deviation from gold standard. The factors "observer" and "cephalogram," regarded as random effects in an ANOVA analysis, and their interaction, each influenced the result, $P < .001$. The deviation from the mean of all observations for antegonion ranged 8 mm with "cephalogram" having a statistically significant influence. The results suggest that neither gonion nor antegonion can be routinely used as valid landmarks in frontal cephalograms. Gonion can, however, be used if first identified in a lateral cephalogram and transferred to a paired frontal cephalogram aided by radiographic indicators combined with a bilateral scrutiny of projection geometry in different planes through gonion and indicator.

KEY WORDS: Antegonion, Cephalometry, Facial asymmetry, Gonion, Radiology.

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Facial asymmetry is characterized by (1) a shift of the midline of 1 or both jaws relative to the cranial midsagittal plane, (2) a difference in facial height between sides, (3) a difference in facial width between sides, or (4) a combination of 2 or more of these features. Skeletal facial asymmetry is mostly a result of unilateral excessive or impaired growth, but can be caused by expanding pathological processes or can be posttraumatic or postsurgical sequelae. In the quest for a method to evaluate skeletal facial asymmetry for diagnosis, treatment planning, and follow-up, different radiographic modalities have been used, all with shortcomings regarding reliability and validity. The problem is in principal two-fold: lack of imaging reproducibility and variation in intra- and inter-observer performance.

The radiographic techniques most used for evaluation of facial asymmetry are panoramic imaging,[1–3], transpharyngeal radiographs,[4] and frontal cephalograms.[3,5–12] The panoramic technique results in a varying degree of image distortion depending on the equipment used. This results in unreliable horizontal measurements and possible deviation between the depicted vertical height and the true height of an object.[13] Furthermore, the technique cannot be expected to detect a difference in mandibular height of less than 6% between sides.[1] The image outcome is highly sensitive to the positioning of the patient in the panoramic equipment.[13] The transpharyngeal technique is, to some extent or in total, based on free hand alignment of patient, film, and focus relative to each other. Hence, the reproducibility of panoramic images and transpharyngeal radiographs is hazardous. In contrast, the positioning of the patient in a fixation device with ear plugs and head support for production of cephalograms allows image reproduction with high accuracy and makes cephalograms suitable for longitudinal comparison.[14]

Facial midline shift is determined relative to the cranial midsagittal plane and can easily be determined in the frontal cephalogram. However, a prerequisite for determination of difference in facial height or width between sides is the identification of specific anatomic landmarks. The landmarks most commonly used are gonion and antegonion.[5–12]

Gonion is defined as the external angle of the mandible projected in a lateral cephalogram by bisecting the angle formed by tangents to the posterior border of the ramus and the inferior border of the mandible. It is an established, reproducible landmark routinely used in lateral cephalometry. The definition of gonion in the lateral cephalogram does not apply to the frontal cephalogram. Instead, the most inferolateral point of the ramal outline at the mandibular angle has been chosen to correspond to gonion. However, significant inter- and intra-observer variation has been reported regarding identification of gonion in frontal cephalograms.[15] The variation indicated a magnitude of identification errors which is unacceptable.

Antegonion is defined as the most superior point of the antegonial notch, relative to the mandibular plane, as projected in the lateral cephalogram.[16] The same definition has also been used in frontal cephalograms,[5,12] although the 2 definitions do not refer to an identical anatomical structure. A study of the ability to identify antegonion concluded that differences between mandibular sides, as measured in frontal cephalograms in clinical practice, might well be due to identification errors.[17]

A relationship between temporomandibular joint (TMJ) dysfunction and facial asymmetry has been discussed in several studies.[7,18–23] Recent experimental investigations in growing rabbits have revealed mandibular asymmetry to develop secondary to nonreducing disk displacement.[24–26] A long-term follow-up based on transpharyngeal radiographs of patients who developed TMJ disk displacement during adolescence indicated that secondary osteoarthrotic changes, with loss of condyle mass later in life, might result in a shorter mandible on the affected side.[4] The availability of a valid method for determination of a reproducible anatomical landmark in frontal cephalograms is a prerequisite for further delineation and evaluation of development of skeletal facial asymmetry secondary to TMJ disk displacement.

The aim of this study was to develop a method to transfer gonion, as identified in the lateral cephalogram, to its correct site in a paired frontal cephalogram. This identification was to be used as the gold standard when determining inter- and intra-individual observer performance at identification of gonion in frontal cephalograms. In addition, inter- and intra-individual observer performance was to be studied at identification of antegonion.

MATERIALS AND METHODS Return to TOC

The material was comprised of 26 pairs of cephalograms. Each pair included a lateral and a frontal cephalogram of the same individual. The radiographic equipment used was a Philips Super Rotalix® x-ray tube (Philips, Germany) with rotating anode and exposure data of 90 kV and between 13 and 16 mAs. The film/screen combination used was Kodak T-mat L film (Kodak-Industrie, France) and Kodak Lanex Medium screens (Kodak, USA). The equipment and the exposure procedure were according to the standard protocol used clinically at the Department of Oral and Maxillofacial Radiology, Umeå University, Sweden. The patient's head was fixed in a custom-made cephalostat with the left side facing the film. The distance from the focus to the film was 170 cm, and the distance from the center of the object to the focal spot was 155 cm. The resulting magnification in the lateral cephalogram ranged between 1.13 and 1.14 on the right side, and between 1.05 and 1.06 on the left side. The magnification of each side was calculated individually for each cephalogram. The magnification in the coronal plane through gonion bilaterally was 1.09. This magnification was used in the frontal cephalograms.

Identification of sides

The cephalograms were obtained with lead markers of different sizes attached to the skin bilaterally over the landmark gonion, as estimated by external palpation. The smaller marker was placed on the left side, since the difference in magnification between sides in the lateral cephalogram enhanced the difference in indicator size, and not the reverse. Hence, the left marker could readily be identified from the right marker. Gonion was identified for both sides in the lateral cephalogram according to the standard definition. Mandibular left side vs right side was identified based on calculations of the inclination of the x-ray beam through gonion on each side and through each indicator (Figure 1). The relative movement of the indicators was determined and related to projection geometry. The information on anatomical characteristics assessed from the frontal and lateral cephalograms in combination was also used. Identification of sides in the lateral cephalogram was made individually by 3 observers, all experienced radiologists. In case of any disagreement between observers, consensus was reached by discussion following a mutual analysis of projection geometry. The identification of sides was checked in a spot test performed on 5 of the subjects. This identification was performed in either of 2 ways: (1) metal indicators were pressed firmly toward the mandibular base on the left and right side, more posteriorly on 1 side, and more anteriorly on the other side. In an additional lateral cephalogram the indicators identified the outline of the bone on both sides, with a distance to the bone of less than 1 mm; and (2) a cannula was inserted inferosuperiorly until there was bone contact with the right mandibular base. In an additional lateral cephalogram, the tip of the cannula identified the outline of the bone on the right side (Figure 2).

Gonion

The vertical vector of the distance between each gonion and the ipsilateral lead marker was measured (Figure 3a) and compensation was made for the enlargement factors. The vertical vector was then transferred to the frontal cephalogram with compensation for the magnification factor in the coronal plane through gonion (Figure 3b). Hence, gonion was bilaterally identified at its correct height in the frontal cephalogram. This identification served as the gold standard.

The intra- and inter-observer performance in identifying gonion, defined as the most inferolateral point of the ramal outline at the mandibular angle, was determined. Five observers (4 radiologists and 1 orthodontist) identified and traced the landmark in each of 21 of the frontal cephalograms. The observers had access to the corresponding lateral cephalograms. The procedure was repeated after approximately 4 weeks to allow for determination of intra-observer performance. The observers were consistently blinded to the lead markers. Two pinholes in diagonal corners of each cephalogram and each tracing served as fiducial points. The distance between each observation and the gold standard identification was measured bilaterally in all cephalograms. Observations superior to a horizontal line through the gold standard identification were given a positive value, and observations inferiorly were given a negative value.

Antegonion

The antegonion landmark, defined as the most superior point of the antegonial notch relative to the mandibular plane as projected in the frontal cephalogram, was identified and traced by 6 observers, all radiologists, in each of the 26 cephalograms. For determination of the intra-observer performance, the procedure was repeated after approximately 4 weeks. To determine inter-observer performance, the site of each observation was identified in relation to a point arbitrarily chosen along the bone outline of the mandibular body. Each observation site had to be able to be connected to the point by a straight line along the mandibular outline. The absolute deviation from the mean of all observations was measured for each observation and analyzed.

Statistics

A 2-way analysis of variance (ANOVA), in which each of the factors “observer,” “cephalogram,” and “observation replicate,” were regarded as random effects, was used to evaluate the variation in observer ability to identify gonion and antegonion as described above. Effects due to these factors were identified as inter-observer, inter-cephalogram, and intra-observer effects, respectively. The interaction between factors “observer” and “cephalogram” was analyzed.

The model used was

$$y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + \epsilon_{ijk}$$

where y_{ijk} are the measurements analyzed, α_i, i = 1, °H, a represents the variation due to cephalogram, β_j, j = 1, H°, b the variation due to observer (the inter-individual observer variation), γ_k, k = 1, 2 the variation due to replicates (the intra-individual observer variation), $(\alpha\beta)_{ij}$ represents the interaction between cephalogram and observer, and ϵ_{ijk} are additive error terms.

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Identification of sides

The right mandibular base outline was projected inferior to the contour of the contralateral side in 19 cephalograms and superior in 7 cephalograms. The spot-test confirmed identification of sides.

Gonion

A total of 210 observations on the left side and 210 observations on the right side were made by the 5 observers.

Left side. On the left side, the observers placed gonion on an average 1.51 mm inferior to the gold standard. The observations varied in location between 17.5 mm superior and 10.0 mm inferior to the gold standard, the range being 27.5 mm. The standard deviation was 4.20 mm and the standard error of the mean 0.29 mm, which deviated statistically significantly from zero ($P < .001$). “Observer” (Figure 4a) and “cephalogram” (Figure 4b) had significant impact on the deviation ($P < .001$). “Replicate” had no significant effect on the result. The interaction between “observer” and “cephalogram” (Figure 4c) had a statistically significant effect on the deviation from the gold standard ($P < .001$).

Right side. On the right side, the observers identified gonion on an average 1.53 mm inferior to the gold standard. The observations varied in location between 6.5 mm superior and 9 mm inferior to the gold standard, the range being 15.5 mm. The standard deviation was 3.16 mm and the standard error of the mean 0.21 mm, which deviated statistically significantly from zero (*P* < .001). "Observer" (Figure 5a) and "cephalogram" (Figure 5b) had significant impact on the deviation (*P* < .001). "Replicate" had no significant effect on the result. The interaction between "observer" and "cephalogram" (Figure 5c) had a statistically significant effect on the deviation from the gold standard (*P* < .001).

Antegonion

Six tracings lacked pinholes and were discarded. Thus a total of 306 observations on the left side and 306 observations on the right side, made by 6 observers, were evaluated.

Left side. The absolute deviation from the mean of all observations on the left side was 0.81 mm as a mean and the standard error of the mean was 0.07 mm, which deviated statistically significantly from zero (*P* < .001). The range was 0.0–5.9 mm and the standard deviation was 1.14 mm. "Observer" did not statistically significantly influence the result (Figure 6a). "Cephalogram" showed a statistically significant effect on the result (*P* < .001) (Figure 6b). "Replicate" showed an effect on the result that was statistically significant (*P* < .01). The interaction between "observer" and "cephalogram" had a statistically significant influence on the result (*P* = .05) (Figure 6c).

Right side. The absolute deviation from the mean of all observations on the right side was 0.68 mm as a mean and the standard error of the mean was 0.06 mm, which deviated statistically significantly from zero (*P* < .001). The range was 0.0–8.2 mm and the standard deviation was 1.05 mm. There was no statistically significant influence on the result by "observer" (Figure 7a). "Cephalogram" had a statistically significant effect on the result (*P* < .001) (Figure 7b). "Replicate" did not have a statistically significant influence on the result. The interaction between "observer" and "cephalogram" (Figure 7c) showed no statistically significant influence on the result.

DISCUSSION Return to TOC

The observers' identification of gonion in frontal cephalograms deviated from the gold standard, with a range amounting to almost 3 cm. This revealed a major difficulty in identifying this landmark in frontal cephalograms. The ANOVA showed that the factors "observer," "cephalogram," and the interaction between "observer" and "cephalogram," all influenced the deviation from the gold standard. Hence, the results support the previous conclusion that the identification error is of unacceptable magnitude.[17] The influence on the result exerted by the factor "observer" reflected that identification of gonion in frontal cephalograms was difficult for the observer and that the definition of the landmark did not allow for an acceptable inter-individual agreement of identification. The influence on the result by the factor "cephalogram" was interpreted to reflect that the landmark definition was impossible to apply due to anatomical variations between subjects. The enhancement of the deviation in identification by the interaction between "observer" and "cephalogram" suggests that the routine use of gonion in frontal cephalograms is invalid.

As regards antegonion, there was significant deviation in individual observations from the mean of all observations, with the maximum deviation amounting to 8 mm. The factor "cephalogram" had an impact on the result for both the left and right sides, implying that a cephalogram that is difficult to interpret causes a significantly greater distribution around the mean than a cephalogram that is easy to interpret. The factor "replicate" influenced the result on the left side, reflecting a difficulty in repeated identification of this landmark. The interaction between "observer" and "cephalogram" affected the result on the left side (ie, the effect by each factor was amplified by interaction).

Even in subjects without obvious facial asymmetry, identification of the left and right sides of the mandible cannot be made in the lateral cephalogram only, as shown in this study. In 7/26 (27%) seemingly symmetrical subjects, the mandibular base outline of the side facing the focus was projected superior to the contralateral outline in spite of the greater enlargement of the side facing the focus. Individual identification of left and right sides of the mandibular outline in the lateral cephalogram was not possible to perform without a paired frontal cephalogram and metal markers in the gonial areas. With analysis of the projection geometry in the paired cephalograms and by scrutiny of enlargement factors for each gonial area and lead marker, a correct identification of sides could be made.

The results of this study support previous studies reporting that landmark identification errors occur in the analysis of frontal cephalograms and are likely to affect analysis of horizontal and vertical delineation of asymmetry between sides.[15,17] The magnitude of identification error in this study emphasizes the risk of false-positive as well as false-negative registration of mandibular asymmetry.

Based on the results of this study, we postulate that if evaluation of facial asymmetry is performed with measurements of height for the left and right side separately, determination of asymmetry in the coronal plane cannot be made without paired lateral and frontal cephalograms. Bilateral radiographic markers and a scrutiny of projection geometry are prerequisites for correct identification of mandibular sides in lateral cephalograms and for identification of gonion in frontal cephalograms.

CONCLUSIONS Return to TOC

If studies of facial height are performed and measurements made in frontal cephalograms, the antegonion landmark is invalid. Without correct identification of gonion, any difference between the left and right side, not exceeding approximately 3 cm, could be attributed to identification error. A technique for correct identification of gonion is provided.

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FIGURES Return to TOC

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FIGURE 1. Lateral cephalogram with gonion marked for the left and right side respectively. A small lead marker is placed on the left side, closest to film, and a larger lead marker is on the right side facing the focus

Click on thumbnail for full-sized image.

FIGURE 2. A cannula (C) is inserted inferosuperiorly until there is bone contact with the mandibular base on the right side, which is thereby identified

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FIGURE 3a. Schematic drawing of the gonial areas corresponding to a lateral cephalogram; gonion is marked for both sides. The vertical vector of the distances from gonion to the lead markers are marked. (A) Distance from left gonion to ipsilateral lead marker. (B) Distance from right gonion to ipsilateral lead marker.**FIGURE 3b.** The vertical vector of the distances A and B from lead markers to gonion bilaterally are transferred to the frontal cephalogram, after recalculation of magnification factors.

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FIGURE 4. Box-plot of deviation from gold standard for (a), “observer” (b), “cephalogram” and (c), interaction between “observer” and “cephalogram” for left gonion. Boundaries of boxes represent first and third quartile of values, line in box represents median value, and lines connected to boxes by vertical bars indicate range of nonextreme values. Extreme values are shown as (i) circles = 2–3 box lengths from the edge of the box, (ii) asterisks = more than 3 box lengths from the edge of the box. “Observer”, “cephalogram”, and interaction between “observer” and “cephalogram” all show a significant influence on the deviation from the gold standard, $P < .001$

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FIGURE 5. Box-plot of deviation from gold standard for (a) “observer”, (b) “cephalogram”, and (c) interaction between “observer” and “cephalogram” for right gonion. Boundaries of boxes represent first and third quartile of values, line in box represents median value, and lines connected to boxes by vertical bars indicate range of non-extreme values. Extreme values are shown as (i) circles = 2–3 box lengths from the edge of the box, (ii) asterisks = more than 3 box lengths from the edge of the box. “Observer,” “cephalogram,” and interaction between “observer” and “cephalogram” all show a significant influence on the deviation from the gold standard, $P < .001$

Click on thumbnail for full-sized image.

FIGURE 6. Box-plot of deviation from the mean for (a) “observer”, (b) “cephalogram”, and (c) interaction between “observer” and “cephalogram” for left antegonion. Boundaries of boxes represent first and third quartile of values, line in box represents median value, and lines connected to boxes by vertical bars indicate range of nonextreme values. Extreme values are shown as (i) circles = 2–3 box lengths from the edge of the box, (ii) asterisks = more than 3 box lengths from the edge of the box. “Observer” has no statistically significant influence on the result. “Cephalogram” show a statistically significant effect on the result, $P < .001$. The interaction between “observer” and “cephalogram” have a statistically significant influence on the result, $P = .05$

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FIGURE 7. Box-plot of deviation from the mean for (a) “observer”, (b) “cephalogram”, and (c) interaction between “observer” and “cephalogram” for right antegonion. Boundaries of boxes represent first and third quartile of values, line in box represents median value, and lines connected to boxes by vertical bars indicate range of nonextreme values. Extreme values are shown as (i) circles = 2–3 box lengths from the edge of the box, (ii) asterisks = more than 3 box lengths from the edge of the box. “Observer” has no statistically significant influence on the result. “Cephalogram” show a statistically significant effect on the result, $P < .001$. The interaction between “observer” and “cephalogram” show no statistically significant influence on the result

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