A method of magnification correction for posteroanterior radiographic cephalometry

Tin-Hsin Hsiao, BS, MS; Hong-Po Chang, DDS, PhD;
Keh-Min Liu, DDS, PhD

Since the introduction of radiographic cephalometry into orthodontics by Broadbent[1] in the United States and Hofrath[2] in Germany, this technique has become quite important for both clinicians and researchers, especially those studying craniofacial growth.[3]

Most of the present cephalometric analyses are based on the use of lateral cephalometric radiographs. The posteroanterior (PA) cephalogram is, however, important for the correct diagnosis and quantification of bilateral structural problems and craniofacial widths. Many clinicians do not routinely use the PA cephalogram.

The PA and lateral cephalograms must be combined for a three-dimensional assessment.[3-6] However, the PA cephalogram presents a problem of differential magnification. The purpose of this study was to present and validate a simple method to correct for magnification using the geometric principle of similar triangles.

Materials and methods

Method of magnification correction

The magnitude of enlargement in the PA headfilm is a function of the distance between the anode and the landmark as well as the distance between the anode and the headfilm.

Using the geometric principle of similar triangles, the craniofacial width at the PA

Abstract

A simple method for magnification correction of width measurements from posteroanterior (PA) cephalograms is presented. Small lead markers were placed on selected landmarks of dry skulls. Lateral and PA cephalograms were obtained for each skull. Seven cephalometric width measurements were selected. Actual widths were deduced from the geometric principle of similar triangles. The magnification factor is the distance between the anode and the transporionic axis, plus or minus the corrected distance of the landmark to the transporionic axis measured from the lateral cephalogram, divided by the distances between the anode and the film. Differences between measurements made directly on the skull and corrected width measurements from the PA films were observed to be very small (<0.50 mm) and statistically insignificant (P>0.05). Paired measurements were of high correlation (r=+0.99). The present method of magnification correction means cephalometric width measurements can be made that are comparable in accuracy with measurements made directly on the skulls.

Key words

Cephalometry • Craniometry • Lateral cephalogram • Magnification correction • Posteroanterior cephalogram • Width measurements

Submitted: January 1996 **Revised and accepted:** June 1996 Angle Orthod 1997; 67(2):137-142.

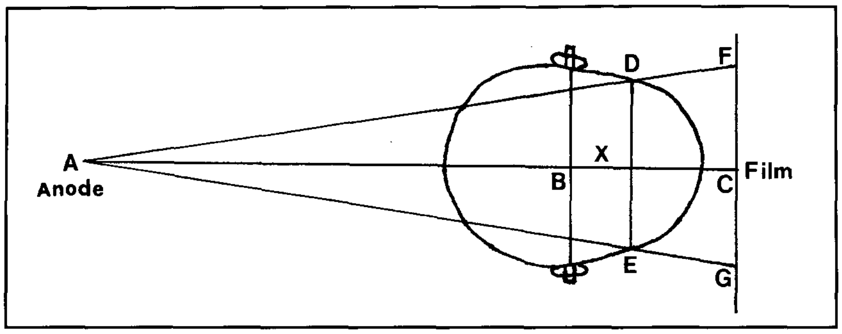

Figure 1

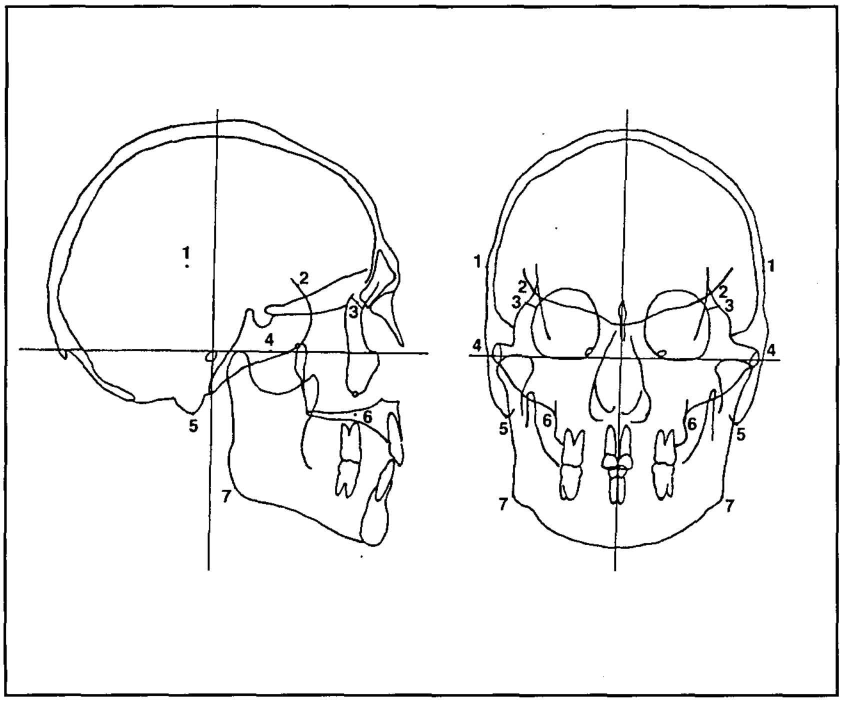

Figure 2

Figure 1
The geometric principles of similar triangles for magnification correction of PA cephalogram.
DE = FG x {(AB ± X)/AC}.
A, anode; AB, anode to transporionic axis distance; AC, anode to film distance; DE, actual width between landmarks in subject; FG, linear measurement between landmarks on PA headfilm; X, corrected distance of landmark from transporionic axis measured on lateral cephalogram of the same subject.

Figure 2
Cephalometric landmarks. 1. Euryon; 2. Anterior cranial base; 3. Frontomalare temporale; 4. Zygion; 5. Mastoidale; 6. Maxillare; 7. Gonion.

cephalogram can be deduced using the following expression:

DE = FG x {(AB ± X)/AC} (Figure 1)

where, A = anode; AB = anode-to-transporionic axis distance; AC = anode-to-film distance; DE = actual width between landmarks in subject; FG = linear measurement between landmarks on PA headfilm; and X = corrected distance of landmark from transporionic axis measured on lateral cephalogram of the same subject.

For convenience, a positive sign was given to landmarks on the frontal side of porion and a negative sign to landmarks on the occipital side. In this study, as the distances AB and AC were kept constant at 150 cm and 165 cm, respectively, width measurements in the PA films could be scaled down as per the magnification factor. This factor is the distance between the anode and the transporionic axis, adding or subtracting the corrected distance of the landmark to the transporionic axis in the lateral headfilm, divided by the distance between the anode and the film. Assuming an anode-to-midsagittal-plane distance of 150 cm and an anode-to-film distance of 165 cm, the enlargement factor for each lateral headfilm was 11/10 (i.e., 165/150).[7] All linear measurements obtained from the lateral headfilms were enlarged by 10% and required correction to compute the real values of craniofacial widths in the skull from the PA film.

Accuracy of the method for magnification correction

Twenty dry adult skulls with mandibles were randomly selected from the collections of the Department of Anatomy, Kaohsiung Medical College.

Small lead markers were taped to the various landmarks prior to placing the skulls in the cephalostat for recording lateral and PA cephalograms. Skull positions for the headfilms were carefully checked. According to earlier studies of geometrical changes on PA and lateral cephalograms in various head positions, it has been concluded that a change within five degrees up-down or left-right rotation is a negligible factor in width or lateral measurements.[8,9] Width measurements obtained from these cephalograms were corrected for magnification factors as per the method described above. The landmarks on both the crania and cephalogram were measured carefully using vernier calipers within a precision of 0.01 mm. Each distance was measured twice on two separate occasions, and the average

Table 1
Comparison of corrected width measurements from posteroanterior cephalogram with direct craniometric measurements on skulls

Skull No.	Maximum cranial width		Anterior cranial base width		Bifrontozygomatic width		Bizygomatic width		Bimastoid width		Maxillary skeletal base width		Bigonial width	
	Craniometric	Radiographic	Craniometric	Radiographic	Craniometric	Radiographic	Craniometric	Radiographic	Craniometric	Radiographic	Craniometric	Radiographic	Craniometric	Radiographic
1	144.40	144.41	93.07	92.80	103.63	104.04	141.95	141.90	118.07	118.13	68.42	68.32	111.81	111.72
2	138.61	138.85	89.17	89.38	105.52	105.82	132.92	132.64	101.72	101.26	63.46	63.61	104.16	103.99
3	138.90	138.83	89.26	89.35	100.81	100.70	121.62	121.33	94.83	95.06	58.05	57.69	86.58	86.52
4	144.97	144.81	93.81	94.10	107.42	107.82	143.30	143.73	103.55	103.45	65.00	65.32	109.55	109.83
5	147.26	147.20	97.71	97.78	102.31	102.26	133.35	133.84	101.00	101.28	62.61	62.85	91.36	90.95
6	149.52	149.48	99.83	100.15	107.31	107.63	137.25	137.18	102.24	102.06	66.46	66.07	100.26	99.87
7	138.56	138.51	88.70	88.64	101.36	101.13	127.30	127.60	101.13	101.20	59.80	60.14	100.46	100.05
8	145.55	146.02	95.20	95.66	104.55	104.86	137.54	137.96	110.09	109.84	65.19	65.34	104.16	104.46
9	128.32	128.32	85.15	84.83	96.40	96.72	122.95	123.28	93.74	94.06	61.46	61.60	102.04	102.23
10	134.00	133.58	86.62	86.72	98.97	99.36	123.11	123.00	95.68	95.40	60.41	60.33	92.65	93.07
11	140.96	141.15	92.32	92.49	101.56	101.71	127.89	128.25	106.11	105.68	59.40	59.81	103.27	102.81
12	145.40	145.42	95.25	95.52	101.33	101.53	135.34	135.41	108.85	108.49	64.73	64.88	97.84	97.46
13	141.35	141.32	90.68	90.59	101.34	100.88	126.74	126.90	97.66	97.91	61.61	61.58	98.76	98.40
14	146.82	146.88	96.12	96.20	107.35	107.13	137.06	137.43	108.36	108.31	69.78	69.52	101.95	101.91
15	148.52	148.06	98.78	98.64	107.50	107.53	139.14	139.32	102.71	102.87	67.99	67.51	111.78	111.81
16	138.12	138.03	87.17	86.94	96.55	96.52	126.29	126.22	102.62	102.87	61.32	61.34	96.15	95.78
17	139.73	139.46	91.40	91.28	100.86	101.03	131.16	131.44	93.50	93.60	66.47	66.59	102.69	102.64
18	141.30	140.90	92.18	92.09	108.72	108.33	134.31	133.83	102.13	101.93	57.34	56.85	105.76	105.63
19	139.09	139.17	90.68	90.59	102.41	102.40	135.41	135.33	100.40	100.65	65.73	65.53	105.51	105.06
20	132.52	132.21	85.42	85.28	93.12	93.49	115.98	115.54	93.92	93.69	58.94	58.85	88.14	88.40

Paired differences <0.05 mm; paired t-test: $P>0.05$; $r = +0.99$ ($P<0.001$).

value was taken as the actual width.

Seven craniometric or cephalometric measurements, representing craniofacial widths, were selected (Figure 2). These common width measurements would be used in a future study. Five of these were in accordance with the definitions given by Martin.[10] The corresponding numbers, according to Martin, are as follows:

1. Maximum cranial width (Eu-Eu): the distance between right and left euryon, which are the most prominent points on either side of the cranium (maximum cranial breadth, Martin No. 8).[10]

2. Anterior cranial base width (ACB-ACB): the distance between right and left sides of the anterior cranial base, as determined from the radiographic shadow of the intersection of the frontozygomatic processes with the lateral extension of the floor of the anterior cranial base on both sides.[11]

3. Bifrontozygomatic width (Frz-Frz): the distance between right and left frontomalare temporale. Frontomalare temporale is the outer edge of the frontozygomatic suture (upper facial breadth, Martin No. 43).[10]

4. Bizygomatic width (Zyg-Zyg): the distance between right and left zygion. Zygion is the most laterally situated point on the zygomatic arch (zygomatic breadth, Martin No. 45).[10]

5. Bimastoid width (Ma-Ma): the distance between right and left mastoidale. Mastoidale is the apex of the mastoid process (mastoid breadth, Martin No. 13).[10]

6. Maxillary skeletal base width (Max-Max): the distance between right and left maxillare. Maxillare is the intersection of the lateral contour of the maxillary alveolar process and the lower contour of the zygomatic process of the maxilla (Jugal point).[4]

7. Bigonial width (Go-Go): the distance between right and left gonion. Gonion is the most inferior, posterior, and lateral point on the ex-

ternal angle of the mandible (gonial breadth, Martin No. 66).[10]

Results

A comparison between the direct measurements on a skull and those obtained by the correction method is presented in Table 1. Differences were very small (<0.50 mm) and are statistically insignificant (P>0.05). Paired measurements are of high correlation (r=+0.99).

Discussion

In cephalometry, the validity of the measurements must be ascertained by comparing the measurements from cephalograms with measurements made directly on the same skull.[12] Baumrind and Frantz[13] have pointed out that landmark identification errors may arise due to the uncertainty involved in locating specific anatomic landmarks on the radiograph. The investigator's experience is an important factor, since an in-depth knowledge of anatomy and familiarity with the radiographic appearance of the skull reduces such errors. Landmark identification errors of greater than 1.5 mm should be avoided, and those greater than 2.5 mm are clearly detrimental.[14]

Correction of differential magnification in the PA cephalogram is neither widely understood nor routinely practiced. Correction of width measurements requires knowing the distance from the landmark to the transporionic axis. This is determined from measurements taken from lateral cephalograms of the same person. Landmarks must be identifiable on both the PA cephalogram and lateral cephalogram. In this study small lead markers were used to accurately identify landmarks on both films. These landmarks were then sought on films of unmarked skulls and living patients, and they were discarded if they could not be located or inferred on both the PA and lateral films. In general, landmarks identified on patient cephalograms are less reliable because the soft tissue reduces the sharpness of the hard tissue image. This study did not investigate these differences between dry skulls and live patients.

From the examination of 20 crania, the outer edge of the frontozygomatic suture, i.e., frontomalare temporale (obtained from the PA film), corresponds with the center of the suture obtained from the lateral cephalogram. This observation was consistent with Vogel's previous findings.[15] The intersection of the lateral contour of the maxillary alveolar process and the lower contour of the zygomatic process of the maxilla, i.e., maxillare (determined from the PA cephalogram), was observed to lay in the same frontal plane as the lowest point of the outline, known as the "key ridge" in the lateral cephalogram.

Anterior cranial base (ACB) point, determined from the radiographic shadow of the intersection of the frontozygomatic processes with the lateral extension of the floor of the anterior cranial base on both sides in the PA headfilm, was also observed to lay in the frontal plane that passes through the pterygoid point (intersection of the inferior border of the foramen rotundum with the posterior wall of the pterygomaxillary fissure)[4] in the lateral cephalogram. The most laterally situated point on the zygomatic arch, i.e., zygion, was clearly discernible in the PA cephalogram. It was observed to lay on the Frankfort horizontal plane in the lateral cephalogram. Zygion was observed to be 35.2 mm in front of the transporionic axis in each lateral film. This contrasts with the earlier report by Adams,[16] who suggested this distance to be 33.0 mm in the lateral cephalogram (inferred from 3 cm in the skull).

The apex of the mastoid process, i.e., mastoidale, and the most inferior, posterior, and lateral point on the external angle of the mandible, i.e., gonion, were usually easily discernible on both the lateral and PA cephalograms. In a few lateral films very obtuse mastoid processes were noted. This might present some difficulty in identification of landmarks associated with mastoidale.

Euryon was the most prominent point on the sides of the cranium, either on the upper squamous part of the temporal bone or on the parietal bone. The bieuryonic axis was determined in each of 18 cases to lie 14.3 mm behind the vertical transporionic axis in the lateral film. The other two cases showed the corresponding distance to be 19.8 mm and 7.7 mm in the lateral films and the corrected cranial width 141.32 mm and 149.48 mm in the PA films, respectively. If the distance between euryon and porion is 14.3 mm, the calculated maximum cranial widths would be 141.99 mm and 148.88 mm, respectively, whereas the actual craniometric widths are 141.35 mm and 149.52 mm, respectively. Thus the errors were less than 1.0 mm. For all practical purposes the bieuryonic axis may be considered to lie 14.3 mm behind the vertical transporionic axis in the lateral film.

Conclusions

The present method for magnification correction enables cephalometric width measurements to be comparable in accuracy to craniometric width measurements. This simple method for magnification correction will facilitate additional research and clinical use of PA cephalograms.

Acknowledgments

This study was supported by Research Grant NSC 85-2331-B-037-086 from the National Science Council, Taiwan, ROC. The work was presented at The Second Asian-Pacific Orthodontic Conference, Nov. 16-18, 1995, Seoul, Korea.

Author Address

Dr. Hong-Po Chang
Department of Orthodontics
School of Dentistry
Kaohsiung Medical College
100, Shih-Chuen 1st Road
Kaohsiung 80708, Taiwan

T.H. Hsiao, lecturer, Department of Anatomy, School of Medicine and PhD graduate student, Graduate Institute of Medicine, Kaohsiung Medical College.

H.P. Chang, associate professor, Department of Orthodontics, School of Dentistry and Graduate Institute of Dental Sciences, Kaohsiung Medical College.

K.M. Liu, professor, Department of Anatomy, School of Medicine and Graduate Institute of Medicine, Kaohsiung Medical College.

References

1. Broadbent BH Sr. A new x-ray technique and its application to orthodontia. Angle Orthod 1931;1:45-66 (reprinted in Angle Orthod 1981;51:93-114).
2. Hofrath H. Die Bedeutung der Röntgenfern- und Abstabsaufnahme für die Diagnostik der Kieferanomalien. Fortschr Orthodont 1931;1:232-258.
3. Broadbent BH Sr, Broadbent BH Jr, Golden WH. Bolton standards of dentofacial developmental growth. St. Louis: C.V. Mosby, 1975.
4. Ricketts RM, Roth RH, Chaconas SJ, Schulhof RJ, Engel GA. Orthodontic diagnosis and planning. Vol. 1. Denver: Rocky Mountain/Orthodontics, 1982:37-147.
5. Athanasiou AE, Van der Meij AJW. Posteroanterior (frontal) cephalometry. In: Athanasiou AE (ed): Orthodontic cephalometry. London: Mosby-Wolfe, 1995; pp 141-161.
6. Jacobson RC. Facial analysis in two and three dimensions. In: Jacobson A (ed): Radiographic cephalometry. Chicago: Quintessence Publishing Co., Inc., 1995; pp 273-294.
7. Honbashi K, Iwasawa T. Orthodontics. 2nd ed. Tokyo: Ishiyaku Publisher, Inc., 1979; pp 175-176.
8. Ishiguro K, Krogman WM, Mazaheri M. A longitudinal study of morphological craniofacial pattern via P-A x-ray headfilms in cleft patients from birth to six years. Cleft Palate J 1976;13:104-126.
9. Ahlqvist J, Eliasson S, Welander U. The effect of projection errors on cephalometric length measurements. Eur J Orthod 1986;8:141-148.
10. Martin R, Saller K. Lehrbuch der Anthropologie. 3rd ed. Stuttgart: Gustav Fisher, 1957; pp 625-643.
11. Wei SHY. Cranial width dimensions. Angle Orthod 1970;40:141-147.
12. Potter JW, Meredith HV. A comparison of two methods of obtaining biparietal and bigonial measurements. J Dent Res 1948;27:459-466.
13. Baumrind S, Frantz RC. The reliability of head film measurements. 1. Landmark identification. Am J Orthod 1971;60:111-127.
14. Major PW, Johnson DE, Hesse KL, Glover KE. Landmark identification error in posterior anterior cephalometrics. Angle Orthod 1994;64:447-454.
15. Vogel CJ. Correction of frontal dimensions from head x-rays. Angle Orthod 1967;37:1-8.
16. Adams CP. The measurement of bizygomatic width on cephalometric x-ray films. Dent Pract 1963;14:58-63.