A Cephalostat for Panoramic Radiography

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Introduction

A number of investigators[1-4] have attempted to measure the rate of tooth eruption. The problem in most of these studies has been the reliability of the radiographic method employed. It is believed that a new approach, using a new technique, is necessary. In this respect, panoramic radiography[5-7] may prove to be the radiographic procedure to use in the search for answers to the eruption phenomenon. The noteworthy characteristic of the panoramic radiograph is that it provides a clear and full view of all the teeth and jaws in their proportional relationship, complete on one film, in a matter of seconds with little discomfort to the patient during the exposure. These features, plus the fact that it is an extraoral method involving minimal radiation hazards, provide an unusually exciting clinical research tool. In spite of these exceptional advantages over conventional radiographic methods, a serious disadvantage to the eventual use of this equipment has been the auxiliary device used in stabilizing and positioning the subject's head during the exposure to insure undistorted symmetrical images. For this reason, a new cephalostat* was designed and constructed to adapt to the Panorex which was the equipment used in this study for taking panoramic radiographs. It was believed that it might be possible to measure the rate of eruption of certain teeth by taking repeated panoramic radiographs with the adapted cephalostat.

In order to measure change it is necessary to use a constant reference point. For this purpose the radiopaque image of the mandibular canal was selected as the potential reference structure. This structure was selected for assessing the panoramic radiograph because it was always present and was easily identified radiographically.

Materials and Methods

The panoramic radiographs produced for this study were taken using the Panorex dental x-ray machine (Fig. 1) developed by the workers at the National Bureau of Standards[8] and manufactured by the S. S. White Dental Manufacturing Company. In this radiographic technique the subject is seated in an upright chair with back rest and arm supports. Cradled above the lap is a metal crossbar connecting the arm rests. A vertical rod containing a plastic chin support is attached at the center of the metal crossbar. Immediately behind the chair and attached to the chair's platform is a vertical column. Projecting horizontally from this column (suspended over the center of the chair) is the x-ray tube and cassette-holding-plate. This tube-cassette-holder complex is adjustable in a vertical plane. The tube and film holder are fixed to rest exactly opposite each other with enough distance between them for the subject's head to be positioned. The vertical level is adjusted to meet the individual height of the subject. The subject is seated and the tube and cassette-holding-plate are lowered alongside the subject's head to capture

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Fig. 1 Subject seated in the Panorex dental x-ray machine, her head oriented with the conventional chin holder.

Fig. 2 Subject seated in the Panorex dental x-ray machine, her head oriented with the new cephalostat.

the lower extremity of the jaw. The subject's jaw rests upon the plastic chin holder.

The kilovolt potential (KVP) and current (MA) are preset and at the flick of the switch, the tube-cassette-holder-complex rotates around the individual's head in a 270° arc. The entire exposure time is thirty-two seconds.

The cephalostat devised for this study (Fig. 2) was patterned after the Broadbent-Bolton cephalostat[9] and completely replaces the plastic chin-holding device on the Panorex.

Zygomatic arch holders, adjustable in three planes, hold the head immobile while the mandible is supported on a chin holder which is independently adjustable of the zygomatic arch mechanism. Metric vernier calibrations are scribed on the instrument to provide repeat positions.

In using this cephalostat, the subject's head is oriented along the Frankfort horizontal plane by means of a pointer fixed to the cephalostat. The plastic chin rest is adjusted (superior-inferiorly) so that the lower rim of the right bony orbit coincides with the tip of the positioning pointer. The head is secured at the arches by tightening the zygomatic arch supports and the stage is set for the exposure to be made.

Subjects

Three hundred subjects were selected to participate in this study: 100 ten-year-olds, 100 fifteen-year-olds, and 100 twenty-year-olds. Each group was further subdivided equally into male and female, so that the 300 subjects comprised six age-sex subgroups of 50 subjects each.

The ten and fifteen-year-old subjects were suburban grade and high school students from metropolitan Kansas City. The twenty-year-olds were patients from the various departmental clinics of the University of Missouri at Kansas City Dental School. This age span was selected to include both the mixed and adult dentitions in the study. Each subject had his mandibular first permanent molar teeth in occlusion and in contact with the mesially adjacent tooth.

All exposures were made using the same KVP (78) and the same MA (10); all films were of the same manufacturer and machine-developed to insure uniform contrast and density.

Definition of the Mandibular Canal

After all subjects were radiographed, each of the resulting films were taped to the surface of the variable intensity viewing table and the following points and lines were drawn. The lines and points were drawn on both right and left sides of the panoramic radiographs.

Point (A) was placed at the deepest concavity in the radiopaque border of the mental foramen. A line (ab) was drawn intersecting (A) and perpendicular to the lower border of the manrible. Point (B) was placed at the point where the line (ab) intersected the lower border. Perpendicular to line (ab) from Point (A), a line (cd) was extended distally about an inch. With a modified Boley gauge, one end was placed on Point (A) and the other extended twenty (20) millimeters along line (cd) to a Point (C). From Point (C) a perpendicular line (ef) was dropped to the lower border of the mandible to intersect at a Point (D). Point (E) was located along line (ef) at the intersection of the radiopaque outline of the lower border of the canal. The length (ED) was then considered as the distance between the lower border of the canal and the lower border of the mandible and is the measurement considered in this study.

The reason the twenty millimeter selection was made is that the lower border of the canal was closest to the mandibular border in that area as indicated by a large number of panoramic films. Also, others[10-13] have reported that this area (approximately between the first and second permanent molars) is the site where the canal is closest to the lower border of the mandible. The mental foramen, as a point of reference, was decided upon because of Tebo's report on the stability of the foramen.[14]

A fine-pointed Boley gauge with vernier caliper was used and each measurement recorded to the nearest tenth of a millimeter. The sharp points of the Boley gauge were pressed into the emulsion of the film to remeasure each film and check the original measurements. Alternate right and left sides of the film were measured and recorded to eliminate possible error in taking similar measurements.

In order to determine a level of accuracy for the cephalostat, thirty patients from the total sample were selected at random. Duplicate radiographs were taken of each of these patients in the following manner: the patient's head was placed in the cephalostat and oriented along Frankfort horizontal. The settings of the cephalastat were recorded and the exposure made. The patient was removed from the cephalostat. With a time lapse the patient was seated again and his head oriented in the cephalostat using the recorded positions of the original setting. In this manner the second exposure was made.

Correlation coefficients were calculated on both right and left measurements of the original and duplicate radiographs. For the total (300) radiographs, an Analysis of Variance test was the statistical method chosen to determine significant differences for the canal distances between sexes, age groups and age-sex subgroup combinations, ie., ten-year-old females, ten-year-old males, etc. Where a significant difference was found in the Analysis of Variance test, pooled variance "t" tests were employed to determine where, within the sexes, age groups, and age-sex combinations, the significant differences occurred.

Results

In the evaluation of the cephalostat's accuracy, it was found that an extremely high positive correlation ($r = 0.93$) of the original to duplicate film measurements existed on both right and left mandibular images. The correlation value was also highly significant ($P < .001$). Of the thirty measure-

A COMPARISON OF THE MEANS AND STANDARD DEVIATIONS OF THE RIGHT AND LEFT MEASUREMENTS OF THE DISTANCE BETWEEN THE LOWER BORDER OF THE MANDIBULAR CANAL AND THE LOWER BORDER OF THE MANDIBLE

GROUPS	MEANS		STANDARD DEVIATIONS	
	RIGHT	LEFT	RIGHT	LEFT
Males	5.91	6.00	1.31	1.30
Females	5.76	5.86	1.06	1.15
10 yr. Olds	5.35	5.38	0.67	0.71
15 yr. Olds	5.93	6.08	1.14	1.23
20 yr. Olds	6.24	6.32	1.46	1.44
10 yr. Males	5.27	5.35	0.65	0.65
15 yr. Males	5.82	5.97	1.10	1.02
20 yr. Males	6.65	6.68	1.60	1.66
10 yr. Females	5.42	5.41	0.69	0.77
15 yr. Females	6.04	6.20	1.17	1.40
20 yr. Females	5.82	5.96	1.17	1.07
Total	5.84	5.93	1.19	1.23

Table I

ments there were only seven differences between original and duplicate film greater than 0.5 mm. The range in variation between all original and duplicate film measurements was from zero to 3.2 mm.

In the entire sample of three hundred subjects, the range of measurements for the distance between the mandibular canal and the lower border of the mandible was from 3.8 mm in a ten-year-old female to 12.5 mm in a twenty-year-old male.

With respect to age groups, the range for ten-year-old males and females was quite similar: 3.8 mm to 7.5 mm for males and 4.0 mm to 7.0 mm for females. Likewise, the range for fifteen-year-olds was remarkably close: 4.0 mm to 10.8 mm for males and 4.0 mm to 10.3 mm for females. However, the range for twenty-year-olds varied considerably: 4.0 mm to 12.5 mm for males and 3.8 mm to 9.0 mm for females. It is interesting to note that the highest mean (6.68 mm) and the lowest mean (5.27 mm) together with the highest standard deviation (1.66) and lowest standard deviation (0.65) occurred between twenty-year-old males and ten-year-old males, respectively.

In the Table attention is directed to the means and standard deviations of the fifteen-year-old females. This particular age group had the greatest mean and standard deviation difference between right and left measurements.

It is important to note this extreme degree of variation because in comparing this group (fifteen-year-old females) to twenty-year-old males, it was found that there was a significant difference ($P < .020$) between right distances but no significant difference between left distances. This was the only instance where significant and nonsignificant differences were found between right and left distances.

An Analysis of Variance was employed to survey the entire sample for possible significant differences between sexes, ages, and their combinations. The test revealed that there was no significant difference between sexes. However, the analysis disclosed that there was a significant difference between age groups. Similarly, significant differences were observed between age groups with regard to sex.

Since the Analysis of Variance indicated that there was a significant difference between age groups, pooled variance "t" tests were applied to the measurements of the three age groups. The "t" tests revealed that there were significant differences between ten-year-olds and fifteen-year-olds ($P < .001$) and between ten-year-olds and twenty-year-olds ($P < .001$). In the remaining combination, fifteen-year-olds versus twenty-year-olds, there was no significant difference.

Probability levels for age groups with regard to sex revealed that eleven of the fifteen combinations are significant, three are not, and one (fifteen-year-old females versus twenty-year-old males) is significant for right measurements but not for the left. All four combinations of ten-year-old males and females compared with fifteen-year-old males and females were significant ($P < .001$). All four combinations of ten-year-old males and females compared with twenty-year-old males and females were significant ($P < .001$).

Inconsistent results were found to occur where fifteen and twenty-year-olds, with regard to sex, were compared. Significant differences existed between fifteen-year-old males and twenty-year-old males ($P < .001$) and between fifteen-year-old males and twenty-year-old females ($P < .001$). A peculiar result was obtained in comparing fifteen-year-old females with twenty-year-old males, as was mentioned previously. In this instance, a significant difference was found on the right side ($P < .020$) but not on the left ($P < .100$). No significant difference was found between fifteen-year-old females and twenty-year-old females.

Finally, the results obtained in comparing males and females within the same age group are noteworthy. The findings disclosed that there was a significant difference between males and females at twenty years of age ($P < .001$), and none between sexes at ten years or fifteen years.

Discussion

The significance of this study is threefold: 1) a new cephalostat has been introduced to the dental profession; 2) a level of accuracy for the new cephalostat adapted to the Panorex dental x-ray machine was established; and 3) the position of the mandibular canal in relation to the lower border of the mandible, as defined for this study, has been determined.

The cephalostat described in this study is significantly different in three ways: (1) it is the first one presented to the profession for exclusive use in panoramic radiography; (2) it supports the head in three positive facial contact areas; i.e., the two zygomatic arches and the bony prominence of the chin; and (3) it eliminates the sensitive area of the external auditory meati as an area of contact and orientation.

Even though this cephalostat is different in many respects, it still satisfies the requisites for quantification of radiographs as defined by Broadbent:[19] 1) the source of the x-ray is constant; 2) the object which casts the shadow (the patient's jaw or head as the case may be) is constant; and 3) the surface upon which the shadow is thrown is constant. The term constant in this context means that these three factors are controlled for each exposure.

In spite of the fact that the cephalostat met all the above requirements, its reliability had to be determined before applying this instrument in any study. A comparison of the original and duplicate measurements made on the radiographs of the distance between the lower border of the mandibular canal and the lower border of the mandible showed negligible differences. A ninety-three per cent correlation existed between the original and duplicate measurements on both the right and left radiographic images of the mandible. This extremely high correlation enables one to place confidence in the reliability of the instrument.

Measurements made on radiographs, panoramic, periapical, lateral jaw, etc., are all biased, i.e., they do not portray the exact size or proportion of the subject.[20] In addition to the general magnification inherent in any radiographic technique, the presence of distortion is a much more serious problem. Distortion is defined as a disproportionate magnification of different structures.[7] Uncontrollable projection distortion is the major fault in radiographic reliability. Error due to other technical factors, i.e., focal spot size, movement of patient, machine and/or both, grain size of film, etc., can be reduced with careful procedures. In order to minimize this distortion factor, previous reports[20,21] suggest using a large number of subjects in radiographic studies of anatomical variation. It was for this reason that 300 subjects were used in this study.

The measurements taken of the distance between the mandibular canal and the lower border of the mandible on the radiographs were analyzed for significant differences between sexes, among age groups, and all possible age-sex combinations. The results revealed that, in the entire sample, there was no significant difference between sexes. However, a significant difference ($P < .001$) was found to exist between males and females at twenty years of age. This finding indicates that only with maturity does the distance between the mandibular canal and the lower border of the mandible become significantly different for males and females. It follows that the postadolescent influence of maturity may be a factor in the significant modification.

In comparing age groups, regardless of sex, the results disclosed that there was a significant increase between ten-year-olds and fifteen-year-olds ($P < .001$). However, no significant difference existed between fifteen-year-olds and twenty-year-olds. This information suggests that between ten and fifteen years of age, a great amount of alteration occurs within the jaws. This observation is consistent with the generally accepted concept that a great degree of facial growth takes place between ten and fifteen years of age.

In comparing ages, with respect to sexes, interesting results were obtained. All four combinations involving ten and fifteen-year-olds showed significant differences ($P < .001$) and all four combinations between ten and twenty-year-olds were significantly different ($P < .001$). These findings compare favorably with the results obtained in comparing age groups, per se. This indicates that age is the variable determining the position of the canal in relation to the lower border of the mandible between ten and fifteen years, at least.

A significant increase existed between fifteen-year-old males and twenty-year-old males ($P < .001$) and between fifteen-year-old males and twenty-year-old females ($P < .001$). However, in comparing fifteen-year-old females with twenty-year-old females, there was no significant difference and, strange as it may seem, the comparison of fifteen-year-old females and twenty-year-old males revealed a significant difference on the right side but none on the left.

This unusual result involving significant differences between fifteen-year-old females and twenty-year-old males is baffling. A scrutiny of the means and standard deviations of the two groups reveals that there is a 0.61 mm mean difference on the right and only a 0.48 mm mean difference on the left. Comparing standard deviations, there is a 0.43 mm difference on the right and only a 0.26 mm difference on the left. Also, consider the standard deviation on the left side of the fifteen-year-old females which was 1.40 mm, 0.23 mm larger than the right standard deviation. In comparing all the right and left standard deviations in the Table, no other numerical difference is greater than 0.10 mm. The standard deviation difference noted in the fifteen-year-old females is more than twice 0.10 mm. Such a large variation occurring on the left side of fifteen-year-old females may be due to the anatomical variation of the sample studied or to a radiographic peculiarity in the manner in which the radiographs were taken. The rotating film-tube complex on the Panorex may have begun its movement about the subject's head from right to left more often than left to right or vice versa to account for this peculiarity.

There has been only one published report of measurements of the distance between the mandibular canal and the lower border of the mandible. Fawcett,[11] in 1895, measured this distance on one dried mandibular specimen which he felt was typical of most mandibles. He found the canal was closest to the border at the interval between the first and second permanent molars and from that point in either direction, the distance increased. The absolute measurements he reported are not applicable because they are taken from an isolated specimen and cannot be compared with the findings of this study.

Tebo[14] and Gabriel[22] have reported the constancy of the distance between the mental foramen and the lower border of the mandible as determined by anthropological measurements on dried human mandibles. The reports are not pertinent in that they give no details concerning age, sexual or hereditary distinctions.

Nevertheless, to verify these reports of Tebo and Gabriel, measurements were taken of the distance between the lower border of the mental foramen and the lower border of the mandible in the three hundred subjects. It was found that there was a mean increase in the distance of 1.38 mm when comparing ten and fifteen-year-olds and a mean increase in the distance of 0.59 mm when comparing fifteen-year-olds and twenty-year-olds. In addition, these means were significant ($P < .001$). This same distance when comparing the males and females of the entire sample showed a mean difference of 0.43 mm. This difference is also significant ($P < .01$). It is quite possible that all of Tebo's and Gabriel's material was of the adult variety which may account for the constancy of their measurements. Also this author believes that the difference can be attributed to the fact that their measurements were taken on gross material, while this author's measurements were taken directly upon radiographs.

Tebo[12] has also reported the position (anteroposterior) of the mental foramen and found it to be approximately one quarter the distance between the symphysis menti and posterior border of the ramus. This observation is worthy of further investigation as it may prove reliable in the future orientation of serial panoramic radiographs.

Brash,[23] in his studies on the growth of the jaws of experimental animals, reported that growth occurs along the entire length of the lower border of the mandible. The increase in the distance between the mandibular canal and the lower border of the mandible observed in the present study may be the same increase which Brash noted in his experimentation.

Since the mental foramen is anatomically but not embryologically associated with the mandibular canal, one might expect to find a similar increase between the mental foramen and the lower border of the mandible as occurs between the mandibular canal and the border of the mandible.[24]

Many observable landmarks are visible upon these panoramic radiographs; to cite the most obvious: lingual foramina, lingula, mental foramen, mandibular canal, coronoid process and the cortical plate of the lower border of the mandible. It is believed that the mandibular canal is stable and that the surrounding structures increase in an outward direction from the canal. A system of geometric designs may yet be devised using the related landmarks to prove this theory. Moss[25] has stated in his functional development of the mandible theory that the mandible arises from a core or bar of tissue wherein the mandibular canal is the center. Should the canal be judged a stable structure, it would lend considerable support to this functional development theory of the mandible.

It is believed that the panoramic

dental x-ray machine, when equipped with the new cephalostat, has a promising future in dental research. It has been shown to be capable of producing duplicate films with a high degree of reliability. This research tool could be of real value in a number of clinical studies in orthodontics and other areas of dentistry. Alteration in tooth position could be measured with a fine degree of accuracy. Angulation and root paralleling of the teeth could be determined before and after orthodontic treatment. The amount of anchorage loss could be assessed during and/or after orthodontic treatment. The degree of arch leveling and the teeth involved could be determined.

In periodontics this instrument may be used in studies to determine the amount and/or rate of alveolar crest destruction in periodontal disease. In pedodontics, aside from its important diagnostic value, it could be used to measure the effect of premature loss of deciduous teeth on the permanent successor and the adjacent teeth. In prosthodontics it might be well suited to measure the amount of vertical closure with the age of the patient. Its greatest value perhaps lies in the area of oral diagnosis and treatment planning. This cephalostat insures panoramic radiographs of fine quality and clarity with little discomfort to the patient and very little effort on the part of the operator. The completeness of the panoramic radiograph is its significant feature.

Panoramic radiography, subjected to the discipline of the new cephalostat adapted to one of the presently available machines, may play as large a role in clinical and basic orthodontic research in the future as cephalometric radiography has enjoyed in the past. Panoramic radiography is not meant to replace cephalometrics, but to augment and bring into sharper focus that particular area about which we are vitally concerned, the teeth and the jaws.

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References

1. Grøn, Anna-Marie: Prediction of Tooth Emergence, *J. Dent. Res.*, 41: 573-585, 1962
2. Fanning, Elizabeth A.: Effect of Extraction of Deciduous Molars on the Formation and Eruption of their Successors, *Angle Orthodont.*, 32: 44-53, 1962
3. Shumaker, D.: A Radiographic Study of the Eruption of the Permanent Mandibular Cuspid, Bicuspid and Molar, M.S. Thesis, *University of Michigan*, 1957
4. Schour, I. and Massler, M.: The Development of the Human Dentition, *J. Am. Dent. A.*, 28: 1153, 1941
5. Kraske, Leonard M., and Mazzarella, Maurice A.: Evaluation of a Panoramic Dental X-Ray Machine, *D. Prog.*, 1: 171-179, 1961
6. Mitchell, Louis, D., Jr.: Panoramic Roentgenography — A Clinical Evaluation, *J. Am. Dent. A.*, 66: 777-786, 1963
7. Kite, Owen E., Swanson, Leonard T., Lewis, Samuel and Bradbury, Edna: Radiation and Image Distortion in the Panorex X-Ray Unit, *Oral Surg., Oral Med. and Oral Path.*, 15: 1201-1210, 1962
8. Hudson, Donald C., Kumpula, John W. and Dickson, George: A Panoramic X-Ray Dental Machine, *U.S. Armed Forces M. J.*, 8: 45-64, 1957
9. Wylie, Wendell L.: Cephalometric Roentgenography and the Dentist, *Am. J. Orthodont.*, 31: 341-360, 1945
10. Anon.: The Inferior Dental Canal, *Dental Surgeon*, 28: 73-74, Feb. 8, 1930
11. Fawcett, E.: The Structure of the Inferior Maxilla with Special Reference to the Position of the Inferior Dental Canal, *J. Anat. and Physio.*, 29: 355-366, 1895
12. Shirasu, Mikio.: Anatomical Relationship Between the Mandibular Canal and the Teeth. *Int, Dent. Cong. (8) Tr. Suppl.*, Sec. 1: 85-86, 1931
13. Gabriel, Alfred: Architecture of the Human Mandible, *D. J. Aust.*, 18: 383-407, 1946
14. Tebo, Heyl G.: Variations in the Position of the Mental Foramen, *D. Items of Interest*, 73: 52-53, 1951

15. Duckworth, W. L. H.: *Morphology and Anthropology*, Cambridge Univ. Press, pp. 238 ff, 1904
16. Hellman, Milo: Changes in the Human Face. *Inter. Ortho. Congress, First Trans.*, pp. 80-120, 1926
17. Kells, C. Edmund: *Three Score Years and Nine*, New Orleans, 1926, Published by C. Edmund Kells.
18. Pacini, A. J.: Roentgenography Anthropometry of the Skull, *J. Radiography*, 3: 230-237, 1922
19. Broadbent, B. H.: A New X-Ray Technique and its Application to Orthodontia, *Angle Orthodont.*, 1: 45-66, 1931
20. Hatton, M. E., and Grainger, R. M.: Reliability of Measurements from Cephalograms at the Burlington Orthodontic Research Centre, *J. Dent. Res.*, 37: 853-859, 1958
21. Adams, J. W.: Corrections of Error in Cephalometric Roentgenograms, *Angle Orthodont.*, 10: 3-13, 1940
22. Gabriel, A. C.: Some Anatomical Features of the Mandible, *J. Anat.*, 92: 580-586, 1958
23. Brash, J. C.: On the Growth of the Jaws and Palate, *Brit. Dent. J.*, 1: 611-776, 1929
24. Arey, Leslie B.: *Developmental Anatomy*, ed. 6, Philadelphia, 1954, W. B. Saunders Co., pp. 190-194
25. Moss, Melvin L.: Functional Analysis of Human Mandibular Growth, *J. Prosth. Dent.*, 10: 1149-1159, 1960

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