EVALUATION OF FRONTAL CEPHALOMETRIC RADIOGRAPHS FOR PATHOLOGY, SKELETAL ANOMALIES, AND VARIATIONS OF NORMAL

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INTRODUCTION

Since 1931 with the advent of the Broadbent-Bolton Cephalometer, orthodontists have had available to them a valuable tool for study of the head and neck. The vast majority of orthodontic literature has dealt with growth and development studies and technical analysis used by orthodontists in the diagnosis and treatment of orthodontic patients. Most of these studies have involved the use of the lateral cephalometric radiograph with little attention given to the frontal (PA) cephalometric radiograph. Except for studies involving skull symmetry, since 1960, there have apparently been only two articles in the orthodontic literature dealing with surveys for pathological entities using cephalometric radiographs. And only one paper in recent years describing the interpretation of the frontal cephalometric radiograph. As one can see, there is a relative shortage of material in the dental literature dealing with cephalometrics and the diagnosis of head and neck pathology.

The frontal cephalometric radiograph allows the orthodontist to view, with relative clarity, the structures of the cranium and the facial complex on one radiograph adding another dimension to the lateral cephalometric radiograph. Though the typical orthodontic patient is apparently a normal individual, the first and foremost consideration in the evaluation of any radiograph should be an evaluation for

underlying pathology. The primary concern of the orthodontist as a health care provider has always been and must continue to be the health and well being of the patient. The best interests of both the patient and the professional are served when a thorough evaluation of that patient's health is foremost in the diagnosis and treatment planning procedure.

The purposes of this study are: (1) to review frontal cephalometric radiographs from the Oregon Health Sciences University, Department of Orthodontics for pathology or skeletal anomalies; (2) to document incidence levels for pathology and skeletal anomalies in a sample population; (3) to establish an appreciation for the individual variation that exists in the evaluation of the radiographs and to establish a basis on which an orthodontist can decide when a referral to an appropriate medical specialist is warranted; and (4) to increase the level of awareness among orthodontists for the usage of the frontal cephalometric radiograph in the diagnosis of pathology and skeletal anomalies.

LITERATURE REVIEW

Cephalometric roentgenography was introduced in 1922 by Pacini[1] in a thesis entitled "Roentgen Ray Anthropometry of the Skull." On the basis of this work Pacini was awarded the Leonard Research Prize by the American Roentgen Ray Society. Basing his technique on existing anthropometric practices, Pacini was able to record the anatomical structures of both dried skulls and living heads on lateral headplates.

In 1931 Broadbent[2] introduced a precise technique for utilizing standardized cephalometric roentgenography to investigate facial and cranial growth. The Broadbent-Bolton cephalometer permitted standardization of orientation of the head thereby enabling one to superimpose serial headplates and their tracings. This development led to longitudinal roentgenographic investigations on growth and development of living individuals.

Hofrath (1931)[3] was also working in the field of cephalometric roentgenography and is often credited as an independent co-developer of the cephalometer along with Broadbent.

After the advent of the Broadbent-Bolton cephalometer, the majority of the dental cephalometric literature dealt with longitudinal investigation of human growth and development. Most notable in this area of research were Brodie,[4] Downs[5] and Broadbent[6,7] in the 1930s and 40s.

More recently the cephalometer has been put to great advantage in growth and development studies by workers like Bjork,[8] Savara,[9] Lewis,[10] Meredith[11] and Popovich.[12]

The technique of cephalometric radiology was not limited to growth and development studies. It has been a valuable aid to the orthodontist to better understand the position of the dentition in relation to the craniofacial skeleton. This information has been invaluable in diagnosis and treatment planning. Various dentofacial clinical analyses have come about since the application of cephalometric radiography as aids for diagnosis and treatment planning of orthodontic cases.

Though the vast majority of papers dealing with cephalometrics in the orthodontic literature address themselves to various analyses and their application to growth and development and treatment planning, the cephalometric radiograph can be helpful as a screening aid for head and neck pathology.

There are several instances in the literature discussing the use of the cephalometric radiograph in reporting evidences of pathology.

Nanda[12] reported on four cases in which conditions of pathological significance were discovered on lateral cephalometric radiographs during routine orthodontic diagnosis.

Bisk and Lee[13] reviewed the headfilms of 513 orthodontic patients. The patients in this study ranged in age from 7.3 years to 27.0 years. Eighteen or 5.5% of the headfilms were classified as having abnormalities or pathology present. In addition to the 18 abnormal findings,

there were seven findings of incidental interest noted on the lateral headfilms.

McSherry[14] reviewed 415 lateral headplates and found that 93 or 22.4% exhibited skeletal anomalies or variations of normal. No evidence of pathology was discovered in this study.

Dahl, et al (1976)[15] reported that cephalometric roentographic examination could aid in the early diagnosis of nevoid basal cell carcinoma syndrome. A roentgencephalometric analysis of eight males and four females (14 to 54 years of age) with nevoid basal cell carcinoma syndrome (NBS) was presented. The main roentgencephalometric features were: proportionate increase in the size of the calvarium, protrusion of the frontal and parietal region, low position of the occipital region, increased intra-orbital distance, increased length of the mandible and mandibular retronathia due to changes in the shape and position of the mandible. These findings were documented on the basis of cephalometric analysis with comparison between the NBS group and a control group. In addition qualitative examination of the radiographs revealed a number of skeletal finds.

Calcification of falx cerebri was found in all 12 cases and calcifications in the sella turcica region occurred in almost all of the individuals. Increased vascular markings in the calvarium were found in one-third of the cases, and the lamboidal suture appeared strikingly open and serrated in about half of the cases. About two-thirds of the patients revealed an enlarged frontal sinus.

Seven of the eight males showed a prominent glabella which was not seen in any of the females. Eight of the examined patients had bifid ribs. Cervical spine abnormalities were present in three cases. Dahl felt that the cephalometric findings suggested a pattern for this syndrome and that roentgencephalometric examination could aid in the early diagnosis of this syndrome.

Mainous[16] reported on a cephalogram that was used to locate a 0.32 caliber bullet in a gunshot wound of the mandible. He felt that the oral surgeon with cephalometric capabilities is often in the best position to help locate foreign bodies of the head and neck. Cephalometric radiographs provide accurate dimensional measurement of the head, both anteriorly-posteriorly and vertically. By the use of the cephalogram, location of foreign bodies in the head and neck can be greatly facilitated.

Rabey[17] used cephalometric roentgenograms to construct analytic histomorphograms which provide three-dimensional statements about the craniofacial structures in a population. He felt that this morphoanalysis of craniofacial disharmony would enable the oral surgeon to assess the disproportion between various parts of the craniofacial complex with three-dimensional validity and accuracy.

Hansman[18] used cephalometric frontal and lateral as well as paranasal sinus films to develop percentile standards based on the roentgenographic measurement of intra-orbital distance and skull thickness. She used healthy children from families of better-than-average economic circumstances in Denver and this group was presented as a reference of

comparison with less healthy children.

Potter and Gold[19] report that the frontal (posteroanterior) view is the best view of the ear. Otolaryngolotists describe this view as the transorbital view because the petrous pyramid and the ear are seen within the orbit if the skull has been positioned properly. No other view demonstrates the ear so well. Etter[45] used the frontal projection in some opacification studies of normal and abnormal paranasal sinuses. He concluded that radiologists should be more conscious of the considerable variation of the paranasal sinuses especially of the sphenoid sinuses.

In an attempt to better evaluate the total skull in three dimensions, several authors have established methods to orient the frontal and lateral cephalometric films. The Bolton study[20] introduced the use of the Bolton Orientator to properly position the two roentgenograms. This device was used to help establish the Bolton Standards. Sassouni[21] used Lo-Lo (bilatero-orbitale), the neck of crista galli, the ear rods and tip of the central incisors to orient the two films. He studied the frontal film with relation to various lines drawn from his landmarks. Ricketts[22] superimposed as Harvold[23] did on the zygomaticofrontal sutures. Ricketts also established a registration point between the two foramina rotunda, almost in the nasal septum. Ricketts[24] has gone a step further and established a frontal analysis.

Frontal (PA) cephalometric films have been used for the study of asymmetry of the face. Thompson[25] reported that when studying facial asymmetry, it must be recognized that there is no truly symmetrical face regardless of race or age of the individual. Sutton[26] has defined

asymmetry as being present when one or more of the facial or cranial bilateral components (bone or soft tissues) are not equidistant from the midline or that the center of each of the unpaired structures does not lie on that line.

Harvold[22] used a line between the frontozygmatico sutures and the perpendicular line through the root of crista galli to study the aberrations in symmetry of a group of 67 children.

Since there has been no common view between workers as to what reference point to use on frontal (PA) cephalometric films, Marmary, et al[27] have advanced the idea of using foramina spinosa to determine skull midlines. They used 86 adult skulls and found a high degree of reliability in quantifying the degree of asymmetry that may be present.

Shad and Joshi[28] used 43 subjects in which there was agreement between three orthodontists that the subject had a symmetrical face and normal occlusion without previous orthodontic treatment. They concluded that normal pleasing and symmetrical faces do exhibit skeletal asymmetry and that asymmetry of the face may be present even if the teeth are in excellent occlusal contact, maximally interdigitated and with upper and lower midlines coinciding.

MATERIALS AND METHODS

Beginning frontal (PA) cephalometric radiographs of 400 orthodontic patients were randomly selected from the files of the Department of Orthodontics at the Oregon Health Sciences University. Of the 400 patients selected, 258 were from the retention files of the Department of Orthodontics and the remaining 142 patients were in active treatment. The ages of the patients ranged from 9 years 1 month to 44 years 4 months. There were 263 females and 137 males.

The frontal (PA) cephalometric radiographs were taken with a Broadbent-Bolton Cephalometer at a film target distance of 60 inches. Kodak Blue Brand in a cassette with a high speed screen was used in taking the films. The machine utilized 20 ma at 85 KVp with an exposure of 2.5 to 2.75 seconds.

The films were examined with a standard fluorescent view box. Each film was scanned for pathologies, skeletal anomalies, or interesting variations from normal. A systematic approach was used in the evaluation of each film to preclude focusing on any particular area and to facilitate a repeatable examination protocol for each film.

First, the calvarium was examined for density, thickness, areas of radiopacities or radiolucencies, and general appearance of the sutures. Secondly, the cranial vault was examined for radiolucencies

or radiopacities. Third, the frontal sinus, ethmoid sinuses and orbits were examined. Fourth, the mastoid and petrous regions of the temporal were examined for any variations from normal. Fifth, the maxillary sinus and nasal area were examined. Due to the transitory nature of maxillary sinusitis and the inability of this study to have access to any follow-up sinus series radiographs, sinusitis was not classified as pathology unless the patient was in active treatment and presented with signs and symptoms to warrant this. Sixth, the maxilla and mandible and dentition were observed. No attempt was made to look specifically at the cervical vertabrae since this particular view of the skull does not lend itself to proper visualization of those structures.

Upon completion of the initial screening of the radiographs in the Department of Orthodontics, selected radiographs were evaluated by a staff radiologist at the Oregon Health Sciences University.

FINDINGS

During the examination of 400 frontal (PA) cephalometric radiographs, it became obvious that one must have a working definition of the term "pathology" in order to differentiate between true overt pathology and skeletal anomalies or variations of normal. Pathology is the scientific study of disease processes and of those changes in the tissues and organs which result from them. Furthermore, pathology carries with it the concept not only of diagnosis but also of referral to the proper sources for treatment.

In lieu of this working definition of pathology as a disease process requiring treatment, we were unable to classify any of our findings as true overt pathology. We did, however, find numerous instances of skeletal anomalies and variants of normal. Table I lists the skeletal anomalies and variations.

DISCUSSION

The most common finding in this population of patients was the presence of pacchionian depressions. These are depressions of the inner table in the posterior frontal and anterior parietal areas near the superior sagittal sinus. These depressions contain the pacchionian granules or bodies which are small localized enlargements of the pia arachnoid that lie in the vertex of the skull. There is no particular clinical significance to these depressions except that in some instances they appear somewhat bulbous and the skull looks thin at its vertex. Occasionally these granules or bodies contain calcium but they are not observed frequently in roentgenograms. When they are visible, they are seen as small punctate calcified shadows immediately adjacent to the inner table. More often only the small depressions or lakes within which lie the bodies are visualized.[29]

Radiolucencies due to blood vessel markings were very common and varied (5.7%). Most often seen are the middle meningeal vessels. A certain amount of difference in size of the right and left meningeal vessels is found occasionally as a normal varient. Many times the venous channels terminate in vascular lakes (lacuna lateralis). The lacunae show considerable variation and usually have no diagnostic or pathologic significance.[30]

In a few patients the diploic veins or veins of Breschet were very well visualized. The size and number of these veins are quite variable. As a rule they are most prominent in the posterior parietal area, where they can assume a stellate radiation. These venous channels may also show localized enlargements suggesting an abnormality. Most often these enlargements are bilateral and this strongly suggests a normal variant. The condition has been termed phlebectasia.[29]

The superior sagittal sinus was very well visualized in 2.5% of the patients. This observation was included because of the possibility of mistaking the sinus for a persistent metopic suture. The suture will have serrated borders while the superior sagittal sinus borders will be smooth.

The metopic suture usually closes by the second decade but can persist throughout life. A persistent metopic suture is found in 8 to 10% of the population,[29] though one study of children below 10 years found a frequency of 15%.[31] Our study found only 2.5%.

Digital or convolutional markings were found in 6.2% of the patients. In general the persons showing the most pronounced markings were below 15 years of age. These digital markings are areas of diminished density separated by strips of bone of normal density.

Digital markings are probably caused by pressure of the cerebral gyri upon the endocranial surface of the calvaria.[32] It is an everyday observation by radiologists that the skulls of children frequently show well defined convolution (digital) markings, and it has been

repeatedly asserted that care is required in using the number or depth of these markings as a criterion for intercranial pressure.

Pilmore[33] stated that "convolutional or digital markings are highly variable in extent and depth; they are usually prominent in children and adolescents during the period of rapid brain growth . . . . The differentiation between the physiological and pathological degrees of prominence of these markings is very difficult."

Macaulay[34] attempted to make this differentiation easier by establishing the range of the appearances in a series of skull radiographs of children without intracranial disease. He concluded that in childhood, convolutional markings have nothing to do with intracranial pressure. This agrees with Caffey's findings. Macaulay's findings were also similar to those of Davidoff[35] who found few markings before 18 months of age, then a rapid increase to four years of age with a persistently high level until about nine years of age followed by a fairly rapid fall until the age of 14 years with a slight increase to age 18. Macaulay found that 15% of his sample showed conspicuous markings. The age range of his study was wider than in this study.

In two films radiopacities were noted in the anterior cranial base. These were variations in the ridging of the bones making up the cranial base. The angulation of the head and the central beam was such that the radiopacities appeared isolated rather than as a ridge. Good knowledge of skull anatomy is essential in differentiating normal variation from dystrophic calcifications.

Other normal calcifications may be seen in skull radiographs such as calcification of the pineal gland. It has been reported to be visible in radiographs in from 33% to 76% of adult skulls, but rarely found in children.[29] Vastine and Kinney[36] developed a chart for determining displacement of the pineal body in lateral roentgenograms of the skull. This has been helpful in identifying tumors.

Other physiological causes of intracranial calcifications are: calcification in the habenular commissure, calcification of the choroid plexus, dural calcifications, particularly in the falx and pacchionian calcifications.[37]

Hyperostosis frontalis interna is a perculiar overgrowth of bone developing on the inner table of the frontal bone. It is usually bilateral and symmetric. It was found in one (0.2%) of our sample. Most of the cases, 94 to 99%, in the series of different authors, have been women.[38] Our patient was also female. The etiology of hyperstosis frontalis interna is unknown, though several workers have tried to associate it with other syndromes such as senility[39] or a part of an endocrine disorder and variously called metabolic craniopathy, the Morgagni syndrome, and the Stewart-Morel syndrome.[40] There is now general agreement that it is of no clinical significance in females.

Salmi, et al[38] studied skull roentgenograms of 982 healthy subjects found an incidence of 12.2% overall. Most changes were seen in women, 16.7%, with only 2.7% found in males. The greatest incidence occurred about the time of the climacterix and during the following 5 to 10 years.

This may account for our low percentage since the ages of orthodontic patients are considerably lower.

A great amount of variation is seen in the paranasal sinuses. One percent of our sample had variations in the mastoid air cells that ranged from extremely well airated air cells, to one case in which a chronic mastoiditis was suspected. Although the mastoid air cells are visible in the PA frontal projection, they are seen to better advantage on the Towne view and the Schüller view.[19]

Six persons in our survey appeared to have large frontal sinuses. This represented 1.5% of our population. According to Etter[41] the normal adult sinus measures approximately 28 mm high, 24 mm wide and 20 mm in depth. Gorlin[42] reported unilateral aplasia of the frontal at 5% and bilateral aplasia of approximately 7%. The sinuses are important in that there are numerous syndromes that can involve them.

Orbital hypertelorism (Greig's syndrome) was seen in 0.5% of our sample. In this syndrome the orbital cavities are more widely spaced than normal. This condition is encountered with on a number of associated anomalies including mental retardation, syndactily, muscular hypotonicity, renal hypoplasia, webbing of the neck, congenital heart anomaly, auditory disturbances, high arched palate, cleft lip and palate, hypoplasia of the maxilla, macroglossia, microdontia and amelogenesis imperfecta and Sprengel's deformity.[43] Hypertelorism may also occur in a variety of craniostenoses and craniofacial dysostoses.[37] Most cases of hypertelorism can be recognized on frontal roentgenograms of the skull. In borderline cases the measurements devised by Hansman[18] can be used.

Wormian bones are small separate ossicles between the sutures of the skull; they are most frequent near the junction of the coronal and lambdoid sutures. A complicated nomenclature has arisen around these highly variable ossicles.[44] A particularly large ossicle is occasionally seen forming the superior portion of the occipital bone and is known as the Inca bone. This bone is of no clinical importance and was found in one of our subjects. They are often associated with other anomalies of the skeleton such as cleidocranial dysostosis and pycnodysostosis.[42]

An impacted cuspid was found in one person and this was treated by exposing it and bringing it into place in the arch with orthodontic forces.

One and seven-tenths percent had a gross asymmetry of the mandible. The frontal PA cephalometric radiograph is a good aid to identify where the gross asymmetries of the skull are in comparison to the clinical impression. Proper positioning of the head is a requirement.

Two patients had objects in their hair that showed up on the radiographs. This points out the need to remove these prior to exposure so as not to cause any confusion in interpretation of the film.

It was apparent from this survey of 400 orthodontic patients that variations of normal is the rule. The more knowledgeable the individual practitioner becomes of normal variations, the more likely he will be to diagnose possible pathology.

SUMMARY AND CONCLUSIONS

Beginning frontal (PA) cephalometric radiographs of 400 orthodontic patients were randomly selected from the files of the Department of Orthodontics at the Oregon Health Sciences University. These radiographs were systematically evaluated for pathologies, skeletal anomalies, and variations of normal. Upon completion of initial evaluation in the Department of Orthodontics, selected radiographs were further evaluated by a staff radiologist at the Department of Radiology, Oregon Health Sciences University.

None of the radiographs demonstrated a true overt pathology. However, 145 of 400 radiographs (36.2%) exhibited skeletal anomalies or variations of normal.

The frontal (PA) cephalometric radiograph can be a valuable tool in the diagnosis of cranial facial pathologies and anomalies. The relatively high percentage (36.2%) of skeletal anomalies and variations of normal exhibited in this patient population points out the necessity for each orthodontist to develop his or her own systematic approach in the evaluation and examination of the frontal (PA) cephalometric radiograph.

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TABLE I

Distribution of Skeletal Anomalies or Variations of Normal

N = 400 radiographs

Findings	No.	% of Total
Pacchionian depressions	53	13.2
Variations of mastoid air cells	4	1
Large frontal sinus	6	1.5
Multiple radiolucencies in the calvarium	23	5.7
Persistent metopic suture	10	2.5
Nasal fracture	1	0.2
Radiopacities in the cranium	2	0.5
Hyperostosis frontalis interna	1	0.2
Well-visualized superior saggital sinus	10	2.5
Gross mandibular asymmetry	7	1.7
Orbital hypertelorism	2	0.5
Wormian bone	1	0.2
Digital markings	25	6.2
Impacted maxillary cuspids	1	0.2
Radiopaque object in hair	2	0.5