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

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INTRODUCTION

Since the advent of the Broadbent-Bolton Cephalometer in 1931, orthodontists have made extensive use of this valuable tool. The vast majority of the dental cephalometric literature deals with growth and development studies and numerous technical analyses used by the orthodontists in the diagnosis and treatment of cases. In contrast to this, there is a relative shortage of material in the dental literature dealing with cephalometrics and the diagnosis of head and neck pathology. Since 1960, there have apparently only been two articles in the orthodontic literature dealing with surveys for pathological entities using cephalometric radiographs.

Due to the nature of the lateral cephalometric radiograph, the orthodontist has the opportunity to view, with relative clarity, the structures of the cranium, the facial complex, and the upper cervical spine on one radiograph. Even though the typical orthodontic patient is apparently a normal healthy individual,the first and foremost consideration in the evaluation of any radiograph should be a pathological evaluation. The primary consideration of any 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 given the top priority.

The purposes of this study are four-fold: first, to review lateral cephalometric radiographs from the University of Oregon Health Sciences Center, Department of Orthodontics for pathology or skeletal anomalies; second, to document incidence levels for pathology and skeletal anomalies in a population of this size; third, to establish an appreciation for the variation that exists in the evaluation of these radiographs and to establish some guidelines that will enable the orthodontist to better realize when to consult with a radiologist or physician for further evaluation; and finally, to increase the level of awareness among practitioners for the usage of this valuable tool 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[2,3,4] introduced a precise technique for utilizing standardized cephalometric roentgenography to investigate facial and cranial growth. The Broadbent-Bolton cephalometer permitted standarization of orientation of the head thereby enabling one to superimpose consecutive headplates and their tracings. This development led to longitudinal roentgenographic investigations on the growth and development of living individuals.

Hofrath[5] (1931) was also working in the field of cephalometric roentgenography and is often credited as an independent co-developer of the modern day cephalometric technique along with Broadbent.

Following the advent of the Broadbent-Bolton cephalometer, the majority of the dental cephalometric literature dealt with longitudinal investigations of human growth and development. The 1930's and 40's saw investigators like Brodie,[6,7,8] Downs,[9] and Broadbent[4] working in this area. Modern day investigators like Bjork,[10] Savara,[11] Lewis,[12]

Meredith,[13] and Popovich[14] have used the cephalometer to great advantage in growth and development studies.

The uses for cephalometric radiography were not limited to longitudinal or cross-sectional growth and development studies. It also proved to be a very valuable tool in aiding the orthodontist to better understand the position of the dentition in relation to the craniofacial skeleton. This information proved to be invaluable in the area of diagnosis and treatment planning. Utilization of this information has led to the development of any number of diverse dentofacial clinical analyses to aid in the diagnosis and treatment of orthodontic cases.

Although the vast majority of papers dealing with cephalometrics in the orthodontic literature deal with various analyses and their application to growth and development and treatment planning, the lateral cephalometric radiograph can also be a very valuable tool in the diagnosis of head and neck pathology.

Higley[15] (1940) discussed the value of lateral cephalometric radiographs by pointing out things seen routinely in the radiographs which normally would not be revealed otherwise. He listed items such as internal and external cranial development including the sinuses, the pituitary fossa, and excessive adenoid growth.

Nanda[16] (1967) reported on four cases in which conditions of pathological significance were discovered on lateral cephalometric radiographs during routine orthodontic diagnosis. The radiographic findings were diagnosed as a foreign body in the nostril, a benign retention cyst of the maxillary sinus, an intrasellar cyst in the area of the tuberculum sella, and a basal cell nevus syndrome of the mandible and maxilla.

Ricketts,[17,18] Linder-Aronson,[19] and Pruzansky[20] have used lateral cephalometric radiographs to study tonsillar and adenoidal tissues both in normal and pathological states. Pruzansky used a lateral projection of the skull to delineate a two-dimensional view of the tonsils and adenoids. Both Pruzansky and Ricketts felt that enlarged tonsils and adenoids contributed to alterations in the respiratory patterns and changes in the kinesiology of the tongue and circumoral musculature with potential deleterious effects. Ricketts[18] coined the phrase "Ricketts' Respiratory Obstruction Syndrome" on the basis of evaluation of tonsils and adenoids from lateral cephalometric radiographs and clinical evaluation. The syndrome includes a mandible that is postured forward, a Class I posterior crossbite, anterior open bite, enlarged tonsils and adenoids, deflected soft palate, mouth breathing, and tongue thrust on swallowing.

Osborne[21] used lateral cephalometric radiographs to report on upper cervical spine anomalies and osseous nasopharyngeal depth. They found that a surprisingly large number (18.8%) of patients with congenital palatopharyngeal incompetence (CPI) also demonstrated anomalies of the upper cervical vertebrae as visualized on the lateral cephalometric headfilm. Cephalograms of the CPI patients were obtained from the roentgencephalometric registry in the Center for Craniofacial Anomalies at the University of Illinois Medical Center in Chicago. The investigation centered on four types of cervical anomalies which are clearly visible on the lateral cephalogram: fusion of C_3-C_4, occipitalization of the atlas, malformation of the anterior tubercle of the atlas, and malposition of the atlas.

Bisk and Lee[22] (1976) 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 3.5% 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. The distribution of abnormalities or pathologies included five adenoid tissue enlargements, one failure in segmentation of the fourth and fifth cervical vertebrae (C-4, C-5), one impacted cuspid at the symphysis, one case of interstitial emphysema, one osteoma of the frontal sinus, one polyp of the maxillary sinus, and eight cases of sinusitus, including five maxillary, two sphenoidal, and one pan. The seven findings classified as interesting included calcification of the interclinoid ligaments, two ponticulus posticus, a poorly developed sphenoidal sinus, thyroid cartilage calcification, ear lobes, and external occipital spurs.

Dahl et al.[23] (1976) reported that roentgencephalometric 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 of the size of the calvarium, protrusion of the frontal and parietal region, low position of the occipital region, increased interorbital distance, increased length of the mandible, and mandibular retrognathia 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 to the quantitative cephalometric analysis, 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 lambdoidal 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 region whereas none of the females exhibited this characteristic. Eight of the examined patients had bifid ribs and cervical spine anomalies were present in three cases. Dahl felt that the qualitative and quantitative cephalometric findings suggested a pattern that is characteristic for this syndrome and that roentgen-cephalometric examination could aid in the early diagnosis of this syndrome.

El-Mofty[24] (1977) used lateral cephalometric radiographs to describe the facial features of patients with ankylosis of the temporomandibular joint. His sample consisted of 38 patients with unilateral ankylosis of the TMJ. The sample population ranged in age from 4 to 23 years. Quantitative analysis showed that the sella-nasion-gnathion angle was larger than normal, the sella-nasion-pogonion angle was more acute than normal, and the angle formed between the lower border of the mandible and the cranial base was greater than normal. Qualitatively, El-Mofty found shortening of the ramus and enlargement of the condyle on the affected side. Accentuation of the antegonial notch on the affected side was seen in certain cases.

Roberts[25] et al. felt that the "peculiar broad curvature" of the mandibulofacial dysostosis (MFD) mandible could be a distinguishing feature of the syndrome and that the curve of the mandible might be genetically determined and not environmentally controlled. This group studied the serial cephalometric radiographs of eight patients presenting the full range of features characteristic for the MFD syndrome. They found a characteristic pattern emerging from the cephalometric analysis of the craniofacial complex in MFD. The body and ramus of the mandible are diminutive and joined by an obtuse gonial angle. The palatal plane is tipped upward posteriorly and the posterior face height is considerably reduced. The combination of the mandibular deformity and the reduced posterior face height results in a severely retrognathic profile. This MFD profile can be categorized as a bird-like or fish-like profile.

Also working in the field of craniofacial dysharmonies, Rabey[26] utilized lateral cephalometric radiographs in the morphoanalysis of craniofacial dysharmonies, and Garner[27] published a cephalometric analysis of Berry-Treacher-Collins syndrome.

Anderson[28] (1972) reported on a 23-year-old female who was referred to the National Institutes of Health because of repeated mandibular fractures. Examination revealed unique abnormalities of bone, especially of the craniofacial skeleton, in the proposita and three of her four sibs. Lateral cephalometric roentgenograms of the proposita and her affected sibs showed highly similar abnormalitites of their mandibles and other facial bones and distinctive spinous processes of the cervical spine. Each had straightening of the mandibular angle and an elongated, pointed, and prognathic chin. The infraorbital ridges were recessed

in comparison with the supraorbital ridges, and the foreheads were relatively prominent. Each affected member of the family exhibited a skeletal Class III malocclusion. There was also calvarial thinning and a pointed mastoid process. Only a paper-thin layer of radiopaque maxillary bone was apparent between the oral cavity and the antrum. There was thinning of both the maxillary and palatine portions of the bony palate, and the malar bone was remarkably slender. Tomograms revealed abnormalities in the contour and size of all demonstrable facial bones. Because the peculiar contours of the mandible, the zygoma, and the other facial bones were unlike those of any previously described anomalies of the facial skeleton the syndrome was named familial osteodysplasia. This particular syndrome is one of several genetic disorders of the face involving malformations of the facial bones including Treacher-Collins syndrome,[29] craniofacial dysostosis (Crouzon's syndrome),[30] acrocephalosyndactyly (Apert's syndrome),[31] cleidocranial dysostosis,[32] cerebro-costo-mandibular syndrome,[33] and orodigitofacial dysostosis (oral-facial-digital syndrome).[34]

Mainous[35] 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.

Kanemura[36] reported on a 12-year-old boy with an unusual face face and hearing loss who was diagnosed as having frontometaphyseal

dysplasia in conjunction with congenital urinary tract malformations and chronic urinary tract infections. The cranial and facial bones of the patient were studied with roentgen cephalometric analysis. Lateral cephalograms showed hyperostosis of the calvarium, prominent supraorbital ridge, "Nazi-helmet" configuration of the cranial vault, absent or hypoplastic frontal sinuses, and micrognathia with antegonial notching and/or hypoplastic ascending ramus. Quantitative cephalometric analysis showed an increased anterior-posterior length of the cranial base, a shortened maxilla, nasion protruded forward and upward, and the mandible was retruded.

Gordon[37] reported on the difficulties of differentiating between craniostenosis and microcephaly on the basis of radiological features demonstrated on plain radiographs of the skull. Craniostenosis is regarded as a condition in which the infant's head is small because the growth of the cranial vault, and that of the brain, is retarded by premature fusion of the sutures dividing the individual bones of the skull. Microcephaly is regarded as a condition in which the infant's head is small because of failure of the brain to grow and thereby provide a stimulus for the growth of the cranial vault. On the basis of a study of skull radiographs of 28 cases of craniostenosis and 57 cases of microcephaly the following conclusions were drawn by the author: 1) premature fusion of the sutures always occurs in craniostenosis but can also occur in some cases of microcephaly where the sutures tend to be narrower than normal; 2) evidence of increased intracranial pressure should not occur in microcephaly and it is by no means universal in craniostenosis; 3) skull size is small in microcephaly but in craniostenosis a considerable degree of compensation for the effects of the

sutural fusion can occur by growth in a direction parallel to the fused suture; 4) abnormalities in the shape of the skull, while frequent in craniostenosis, can also occur in microcephaly. Thus, while no single radiographic feature can afford an absolute distinction between the two conditions, the summation of radiographic findings will do so in most cases.

MATERIALS AND METHODS

Beginning lateral cephalometric radiographs of 415 orthodontic patients were randomly selected from the files of the Department of Orthodontics at the University of Oregon Health Sciences Center. One hundred of the patients were in active treatment and 315 were selected from the retention files of the Orthodontic Department. The patients' ages ranged from eight years nine months to 45 years nine months. There were 275 female patients and 140 male patients.

The lateral cephalometric radiographs were taken with a Broadbent-Bolton Cephalometer at a film target distance of 60 inches. This machine utilizes a rotating anode at a current of 20 milliamperes. Exposure time was 1.2 seconds at 85 KV.

The films were examined with a standard flourescent 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 cervical vertebrae were examined for size, position, areas of ossification, etc. Secondly, the cranium was examined for density, thickness, and areas of radiopacities or radiolucencies. Third, the sinuses were observed. Due to the transitory nature of maxillary sinusitis and the inability in this particular study to take follow-up radiographs, we did not classify sinusitis as pathology unless the patient was in active treatment and

presented with clinical signs and symptoms to warrant this. Fourth, the adenoidal and tonsillar lymphoid tissues and nasopharyngeal airway were examined. As with sinusitis, adenoidal and tonsillar hypertrophy and diminished nasopharyngeal airway were considered only if the patients presented with clinical symptoms to substantiate radiographic findings. Fifth, the sella turcica and cranial base were examined. Sixth, the mandible and maxilla and dental complex were observed. Finally, the hyoid region was examined.

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

FINDINGS

During the examination of 415 lateral cephalometric radiographs, it becomes 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 from 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 light 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 or variations from normal.

Table I indicates the distribution of skeletal anomalies or variations from normal.

Table II lists the skeletal anomalies and variations.

DISCUSSION

The most common finding in this study was a radiopaque bridging of the atlas or first cervical vertebra. The proper term for this skeletal anomaly is "Ponticulus Posticus" and it occurred in approximately 10.1% of this particular patient population. The cause of this radiographic anomaly is an ossification of the posterior atlantooccipital membrane. The posterior atlantooccipital membrane, broad but thin, is connected above to the posterior margin of the foramen magnum; below, to the upper border of the posterior arch of the atlas. On either side this membrane is defective below, over the groove for the vertebral artery, and forms with this groove an opening for the entrance of the artery and the exit of the suboccipital nerve. The free border of the membrane, arching over the artery and nerve, is sometimes ossified.

In approximately 2% of the films, a malposition of the atlas was noted. In any instance of a suspected malposition or malformation of C-1, C-2, etc., one must first consider the flexion of the cranium and the effect that this flexion would have on the position of the cervical vertebrae. Follow-up films, without flexion, should be taken to ascertain the true positions of these structures. Knowledge of the normal anatomy and position of the cervical vertebrae will enable one to more critically evaluate these structures and their relation to normal head positioning in cephalometric work and orthodontics.

In one head film (0.24%) an incomplete calcification or development of the posterior arch of the atlas was noted.

Two and two-tenths percent of the radiographs studied revealed a bridging of the sella turcica. This is a normal variation and is due to the ossification of one or more of the intrinsic ligaments of the sphenoid. The more important of these are: the pterygospinous, stretching between the spina angularis and the lateral pterygoid plate; the interclinoid, a fibrous process joining the anterior to the posterior clinoid process; and the carotico-clinoid, connecting the anterior to the middle clinoic process. This bridging of sella turcica, in addition to the large range of sizes of a normal sella, is a prime example of normal variation of a structure.

A finding of an external occipital spur was evident in 2% of this patient population. This represents an ossification of the ligamentum nuchae, which is a fibrous membrane representing the supraspinal ligaments of the lower vertebrae. It extends from the external occipital protuberance and median nuchal line to the spinous process of the seventh cervical vertebra.

Foreign bodies were noted in three radiographs, representing 0.7% of the patient population. The first was amalgam fragmentation secondary to a retrograde amalgam fill on an endodontically treated tooth. The second was amalgam fragmentation secondary to routine restorative dentistry. The third was apparently a B-B or metal fragment located possibly in the cheek.

Condensing osteitis was identified in three radiographs, representing 0.7% of the patient population. Condensing osteitis is a localized, low-grade, chronic inflammation of the bone marrow that is

associated with bone formation rather than more typical bone destruction. It can occur at any age and the mandibular molar area is the most commonly affected site. The lesion does not require treatment. It is important, however, on the differential diagnosis to rule out other radiopaque lesions that would require treatment.

Large adenoids with decreased nasopharyngeal airway space were found on three radiographs taken from an active patient file of 100 patients. Two of the three patients were examined and found to demonstrate clinical signs consistent with the radiographic findings. The first patient had a medical history of obstructed nasal breathing and recurrent adenoidal and tonsillar infection and was scheduled by her pediatrician and surgeon for the removal of her tonsils and adenoids. The second patient was a chronic mouth breather with a long, narrow maxilla, anterior open bite, and a tendency toward posterior bilateral crossbite.

The lateral cephalometric radiograph is a two-dimensional representation of three-dimensional structures. Enlarged adenoidal and tonsillar tissues and a decreased nasopharyngeal airway as viewed radiographically should not be considered diagnostic in and of itself. There is much controversy within the medical profession with regard to the role of adenoidal and tonsillar lymphoidal tissue and the criteria for the removal of these. Dental workers such as Ricketts,[18] Harvold,[38] MacNamara,[39] and Linder-Aronson[19] have been instrumental in research relating tonsils and adenoids to mouth breathing with their resultant affect on the developing dentition. This is an area of active research directly related to orthodontics and the radiographic visualization and clinical examination of these structures should become a part of each patient evaluation.

Two radiographs exhibited impacted or ectopically unerupted permanent teeth other than third molars. A palatally impacted maxillary cuspid was subsequently surgically uncovered and moved into the arch. The unerupted lower second bicuspid was blocked out of the arch due to crowding and was extracted prior to fully banded orthodontic therapy.

Two radiographs showed radiopaque ears which can be considered normal variation. However, due to the radiopacity of these structures, there is a certain amount of superimposition over other structures in the mastoid and cervical areas which must be considered when evaluating these areas.

One patient with achondroplastic dwarfism was treated orthodontically at the University of Oregon. His series of lateral cephalometric radiographs demonstrated spinal chord compression, a congenitally small spinal chord, and multiple areas of radiopaque materials used for myelograms. Also evident were an enlarged frontal sinus, hypoplastic midface area, and relative mandibular prognathism due to midfacial hypoplasia.

The lateral headplate of a 22-year-old female patient exhibited multiple radiolucencies beyond the normal range of the mastoid air cells. Also present were patent sutures in the occipital area of the skull. Once again, this was an expression of variations of normal.

Variations in sizes and shapes of various cranial sinuses were evident in 2.4% of the patient population. The frontal sinus exhibited the greatest amount of variation, ranging from a large cavernous sinus with frontal bossing to a nonexistent sinus in a few cases.

Throughout the course of examination of 415 lateral cephalometric radiographs, it becomes obvious that variations from normal become the

rule rather than the exception. Each succeeding radiograph that shows a new variation of normal expands the parameters of knowledge with regard to the structure and the practitioners' knowledge of it.

SUMMARY AND CONCLUSIONS

Beginning lateral cephalometric radiographs of 415 orthodontic patients were randomly selected from the files of the Department of Orthodontics at the University of Oregon Health Sciences Center. The radiographs were systematically evaluated for pathologies, skeletal anomalies, and variations from normal. Upon completion of initial evaluation in the Department of Orthodontics, selected radiographs were further evaluated by a staff radiologist at the Radiology Department, University of Oregon Health Sciences Center.

None of the radiographs were classified as demonstrating true, overt pathology. However, 93 of 415 radiographs (22.4%) exhibited skeletal anomalies or variations from normal.

The lateral cephalometric radiograph is a valuable tool in the diagnosis of head and neck pathologies and anomalies. The relatively high percentage (22.4%) of skeletal anomalies and variations from normal exhibited in this patient population points out the need for each orthodontist to develop his or her own systematic approach in the evaluation and examination of the lateral cephalometric radiograph.

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TABLE I

Age	# of Males	(Skeletal Anomalies Variations of Normal)	# of Females	(Skeletal Anomalies Variations of Normal)
Under 10 yrs.	1	(1)	9	(0)
10 yrs. - 12 yrs. 11 mons.	50	(11)	84	(13)
13 yrs. - 15 yrs. 11 mons.	58	(16)	107	(13)
16 yrs. - 18 yrs. 11 mons.	17	(7)	38	(6)
19 yrs. & above	12	(6)	35	(11)

TABLE II

Distribution of skeletal anomalies or variations from normal. N = 415 radiographs

Finding	No.	% of Total
- Ponticulus Posticus (C-1 Bridging)	42	10.1%
- Malposition of C-1 (Atlas)	8	1.9%
- Incomplete Calcification of C-1	1	0.24%
- Bridging of Sella Turcica	9	2.2%
- External Occipital Spur	8	2.0%
- Foreign Bodies	3	0.7%
- Condensing Osteitis	3	0.7%
- Large Adenoids with Decreased Nasopharyngeal Airway	3 (of 100)	3.0%
- Impacted Lower 2nd Bicuspid	1	0.2%
- Impacted Upper Cuspid	1	0.2%
- Radiopaque Ears	2	0.5%
- Achondroplastic Dwarfism	1	0.2%
- Multiple Radiolucencies and Patent Sutures (Adult)	1	0.2%
- Variations of Frontal, Sphenoid, and Mastoid Air Sinuses	10	2.4%