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CEPHALOMETRY IN ORTHODONTICS – AN OVERVIEW

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Abstract
Orthodontic records are an essential supplement to history and clinical diagnosis for the formulation of a comprehensive treatment plan. Cephalograms are one among these records. From cephalometric analysis one can check the position, size of jaws and their relation with each other. Also it these give information regarding proclination, retroclination of teeth and growth pattern of patient. Cephalograms are also used to evaluate treatment results by comparing pre and post treatment cephalometric values of patient. As malocclusion may be skeletal of dental in origin. For appropriate treatment one should aware about the actual problem of patient which may be related to discrepancy in jaws or dentition in both the arches. Cephalometric analyses help in diagnosing which part of face is at fault and need correction. Thus cephalograms are useful in orthodontics as providing information for diagnosis and treatment planning.
Keywords: Cephalograms, Steiner's analysis, Tweed's analysis, diagnosis, treatment plan.

Introduction

Orthodontic records are an essential supplement to history and clinical diagnosis for the formulation of a comprehensive treatment plan. Records in medicine, in general and orthodontics, in particular, are of greater significance since they are the only evidence of pretreatment occlusion, which is irreversibly altered by the treatment.[1]

The records are essential to back reference and analyse treatment outcome, success and failures. They are the most reasonable evidence to patient–doctor and medico legal disputes. Records are most useful aid in education and research. The production, retention and archiving of precise and accurate patient records is an essential part of the orthodontists' professional responsibility. Records must be permanent, lasting, durable and should remain unaltered.[2] The vital information required to diagnose a malocclusion and develop an orthodontic treatment plan consists of a record of detailed history, clinical examination and other essential diagnostic investigation records.

These include the 3D imprint of the existing malocclusion/occlusion through study models or intraoral scans, the face in profile through photographs, craniofacial skeleton through cephalograms and status of dentition via X-ray (s). Additional investigations must be performed in cases of complex situations.

The essential or minimum diagnostic records:

The minimum set of orthodontic records includes study models, clinical photographs, panoramic and lateral cephalometric X-rays. Although in recent times concern views on the essentiality of X-rays are drifting to exclude those children whose malocclusion is such that X-rays will not add substantial information to clinical findings.

Additional records and investigations:

These may include additional X-rays such as occlusal views, PA cephalograms, tomograms of TMJ, 3D computed tomograms, biochemical studies related to bone metabolism and technetium scan.

The nature and severity of deformity and search for aetiology would decide the type of further investigations to be carried out.

For those involved in treating the malocclusions there is no excuse of being illiterate in the subject of cephalometrics. Cephalometrics can reveal important anatomical information relative to internal structures of the maxillofacial complex of a given case that is totally inaccessible by any of the other means available, either two-dimensional (radiological) or three dimensional (Model analysis).[3]

Cephalometrics has not been solely the exclusive instrument of orthodontics, but was initiated originally in the 18th century by the physical anthropologists that used it as a method of comparing the fossil remains of the skulls of early men1. Even though the science of Cephalometrics can be a useful diagnostic and evaluative tool for the periodontist, the prosthodontists, the oral surgeons and the general practitioners of dentistry, it is seen that it has primarily remained within the province of the orthodontic profession.

The assessment of craniofacial dimensions is not a new skill in orthodontics. The earliest method was used to assess facial proportion from artistic point of view, with beauty and harmony as the guiding principles. By the sixteenth century the artist Durer and Da Vinci had sketched series of human faces with straight lines joining homologous anatomic structures; variations in the lines high lightened structural differences among the faces.[4]

Cephalometrics had its beginning in craniometry. For many years, anatomists and anthropologists were confined to measuring craniofacial dimensions using the skull of long-dead individuals. (Neanderthal and Collognon people whose skulls were found in European Caves in 18th and 19th centuries).[1] Applying these principles to craniometry to the living, however, was limited by the inaccuracies resulting from having to measure skulls through varying thickness of soft tissue. Much later, anthropologist invented an instrument, the craniostat, for orienting dry skull, which can be said to be the forerunner of cephalometry.[1]

Sir Wilhum Conrad Roentgen (1845-1925)[5] discovered X-ray on the night of November 8th 1845 which drastically changed the entire medical world. The concept of standardized radiographic head images was reported by **Pacini,[5]** who in **1922** demonstrated the basic procedure of cephalometrics whereby subjects were positioned to the cassette with gauze bandages at a distance of 2m from the X-ray tube. It was not until **1931** that **Hofrath[4]** in Germany and Broadbent[2] in the United States simultaneously and independently developed standardized method for the production of cephalometrics radiographs, using special holders known as cephalostats, to permit assessment of growth and of treatment response. At the same time Simons system of gnathostatics, a method for orienting orthodontic casts, was in use. These ideas from anthropometric and gnathostatics naturally evolved and fused into a new technology: radiographic cephalometrics.

Cephalometric analysis which is sensitive not only to the position of the teeth within a given bone, but which is sensitive to the relationship of the jaw elements and cranial base structures, one to other. In short, the analysis proposed is an effort to relate teeth to teeth, teeth to jaws, each jaw to the other, and jaws to the cranial base.

Cephalostat

Cephalometrics involves making the measurements from lateral and frontal head radiographs taken with the head held in a fixed position. The cephalostat helps to hold the head in predetermined fixed position.[6]

1. Cephalometric Equipment:

A cephalometric apparatus consists of cephalostat or a head holder, an X-ray source and a cassette holder.

Cephalostat are of two types.

A. The Broadbent – Bolton method[7] utilizes two sources and two film holders so that the subject need not be moved between the lateral and postero-anterior exposures. It makes more precise three-dimensional studies possible but precludes oblique projections. In Broadbent technique, a recording of the distances from the mid sagittal film and also the distance of the frontal films surface from the porionic axis. It allows for direct orientation of the frontal to the lateral, for transfer of right and left structures peripheral to the midline, the lateral x-ray film to the frontal film and reverse also. This orientation is of significance assistance not only in discerning right and left structures but also where correction might be necessary for a frontal radiograph in which the head is tilted down or up from the Frankfort plane relation.

B. The Highley method[5,6] used in most modern cephalostats use one X-ray source and film holder with a cephalostat capable of being rotated. The patient is repositioned in the course of the various projections. Highley places a lead diaphragm with a small aperture in the center directly in front of the x-ray tube so that the anterior edge of the opening is close to the path of the central X-ray.

2. Conventions in taking Cephalograms[5,6,8]:

A. The Lateral Projection – The midsagittal plane of the subject's head is conventionally placed at 60 inches (152.4 cm.) from the target of the x-ray tube with the left side (European convention is the right side) of the subject

towards the film. The central beam of the x-ray coincides with the transmeatal axis. i.e., with the ear rods of the cephalostat. Under most circumstances, the distance from the midsagittal plane to the film is held constant usually at 7 inches (18 cm). In the Broadbent Bolten Cephalometer, this distance varies according to the subject. The patient's head is placed with the Frankfort plane parallel to the floor and the subject's teeth together in their usual occlusal position.

B. The postero-anterior projection - The head is rotated by 90 degrees so that the central ray perpendicularly bisects the transmeatal axis. It is crucial that the

Frankfurt plane should be accurately horizontal, because when the head is tiled, all vertical displacements measured are altered.

The safety feature of the cephalometric technique includes the use of a 90 K.V. peak and the double emulsion film sandwiched within the intensifying screen. It has the advantage that these films have moderate speed as well as wide latitude so that the detailed record of the soft tissue is possible.[3]

Most contemporary cephalometers used in orthodontic offices incorporate the basic elements of roentgenographic cephalometry but utilize only one x-ray source with the associated ability to rotate the head holder 90 degrees to take a complimentary frontal view. Cephalometers that have provision for taking panoramic radiographs are also available for clinical use.[3]

Cephalometric roentgenograms require the following conditions[6]:

1. The sagittal plane of the patient's head for the profile view and the vertical plane for the postero-anterior view must be parallel with the film.
2. The central x- ray from the tube must pass through the axis of the ears (porion) and must strike the x-ray film at right angles when taking the profile views. When taking the posterior views the central X-ray should be on a level with the porion plane or the ear holders and at a right angle to the film.

Adjustments of cephalometer[6]

1. The patient is seated upright so that the right side faces the x-ray tube. The chair is elevated until the external acoustic meateus. The auditory canals are at the height of the ear rods.
2. The operator places a hand on the patient's head while the ear rods are drawn into the ear canals. The ear rods prevent horizontal rotations of the head. The head is then rotated vertically until the inferior margin of the left orbit is horizontal to the ear rods.
3. The holder in the anterior part of the cephalometer then is adjusted against the Nasion to keep the head in the position. The patient's head is thus oriented in the Frankfurt horizontal plane.

Classification of analyses

I. Methodological Classification[6]

The basic units of analysis are angles and distances in millimeters (Lines) Measurements (in degrees or millimeters) may be treated as absolute or relative, or they may be related to each other to express proportion and correlations.

Angular Analysis

The basic unit is angle or degrees.

Dimensional analysis considers the various angles in isolation, comparing them with average figures. Down's analysis is of this type.

Proportional analysis is based on comparison of the various angles to establish significant relations between the separate parts of the facial skeleton. **Koski's (1953)[4]** analysis belongs to this group and was developed further by **Koski and Vorolainon (1965)[4]**. The result obtained with this analysis gives the relation between the basic reference planes OP-N and OP-Pog in percent.

Analysis to determine position: Angular measurements may also be used to determine the position of parts of the facial skeleton. The SNA and SNB angles, for example, give the relations between the maxillary and mandibular bases and the cranial base.

Angular measurements on their own are not normally sufficient for cephalometry and linear measurements will be needed in addition.

Angular analyses have certain deficiencies[6]:

- The lines are drawn in relation to a primary reference plane, on the premise that this remains constant.
- If this plane shows deviations from the mean, the analysis is not reliable. Measurements are often related to particular norms or mean values.
- These norms are however subject to a number of factors, such as age, sex, hereditary and ethnic predisposition, etc.
- They are based on averages and in the individual case. It is the deviation from the mean that is characteristic.

Linear Analysis

For linear analysis, the facial skeleton is analysed by determining certain linear dimensions between anatomical points or constructed points. In almost all the analysis certain parameters utilize linear measurements.

II. Orthogonal analysis

In this analysis a reference plane is established with the various points projected on to it perpendicularly, after which the distances between the projections are measured. Orthogonal analysis may be partial or total. Total orthogonal analysis may be geometrical or arithmetical. The De Coster method is a total orthogonal geometrical analysis.

For the arithmetical method, the reference points are projected on to a horizontal and vertical reference plane and the distances between the points on these planes are determined.

Partial orthogonal analysis involves orthogonal assessment of only part of the facial skull. **Wylie (1947)[9]** for instance used the Frankfurt horizontal plane as the reference plane. He projected a number of reference points perpendicularly on to this and measured the distances between the points thus obtained in the plane. The method differs from total orthogonal arithmetical analysis in that measurements are always made in one plane only.

The most widely known method is the Sassouni analysis (1955), with the reference points not projected perpendicularly, but by drawing arcs with the aid of compasses.

Dimensional, linear analyses are based on valuation of certain linear measurements, either direct or in projection.

The direct method gives certain linear measurements (e.g. the length of the mandibular base) as the distance between two reference points. The results are given in absolute terms, so that age also has to be taken into account for their interpretation.

Projected linear dimensional analysis determines the distances between certain reference points that have been projected onto a reference line.

Proportional linear analyses are based on relative rather than absolute values. The different measurements are compared to each other[4], without reference to norms.

III. Normative Classification:

Analysis may also be classified according to the concepts on which normal values have been based.

Mono-normative Analysis.

E.g. Tweeds and Margoli's Triangle

The arithmetical norms are average figures based on angular, linear or proportional measurements. Geometrical norms are average tracings on a transparent sheet. Assessment consists in comparing these with the case under analysis. These methods merely provide rapid orientation.

The disadvantage of mono-normative analysis is that individual parameters are considered in isolation. Nor do they necessarily represent a normal average as deviations in the individual dimensions of the jaws and face may compensate each other so that occlusion is normal. Just as normal measurements may cumulatively tend to one end of the range of normal variation, the sum total being malocclusion. Mono-normative analyses are suitable only for group studies, and not for diagnostic purposes.[5]

Multi-normative Analysis.

For these, a whole series of norms are used, with age and sex taken into account Example of this analysis Mc Namara analysis.

IV. Correlative Analysis.

These are used to assess individual variations of facial structure to establish their mutual relationships, Correlative analysis are the most suitable for diagnostic purpose, and are used as such by most authors. Examples are Coben's analysis, quadrilateral analysis by DiPolo.

V. Classification According to the Area of Analysis[4]:

The various analyses may involve limited areas or the whole of the facial skeleton.

Dentoskeletal Analysis.

These analyses involve the teeth and skeletal structures. They may be made from normalateralis, norma-frontalis, or three – dimensionally. A more recent development is three – dimensional stereometric analysis, but this is not yet fully developed for clinical use.

Soft tissue analysis

These may involve the whole profile in normal lateralis, or certain structures only. We usually do a partial lateral soft tissue analysis, for example Analysis of lips in a cephalometric radiograph.

Functional Analysis

Cephalometric radiographs may also be used to assess functional relations such as the occlusion to interocclusal space relationship in norma lateralis and norma-frontalis.

Uses of cephalogram

1. Cephalograms are useful to study of Craniofacial Growth – Serial cephalometric studies have helped in providing information regarding:[5,6]

- The various growth patterns
- To establish standard norms against which other cephalograms can be compared.
- Prediction of future growth
- Predicting the consequences of particular treatment plan.
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2. Diagnosis of Craniofacial deformities – Cephalograms help in identifying, locating and quantifying the nature of the problem. The most important result being differentiation between skeletal and

dental mal-relationship.

3. Treatment planning- By helping in diagnosis and evaluation of craniofacial morphology, cephalometrics help in developing a clear treatment plan. Even prior to starting orthodontic treatment an orthodontist can predict the final position of each tooth within a given patient craniofacial skeleton.
4. Evaluation of treated cases- Detail cephalograms permit the orthodontists to evaluate and assess the progress of treatment and also help in guiding any desired change. Cephalometrics has also helped in revealing the much concerned the nature of orthodontic relapse and stability of treated malocclusions.
5. Application of cephalometrics - Finds its value in cine flourography where the movements of the tongue and soft palate can be studied.
6. Orthodontists have the chance to detect any asymptomatic cervical spine abnormalities in the lateral cephalogram. The lesions of the skull may also be detected in frontal and lateral cephalograms.
7. Cephalograms can be used as an adjunct for estimation of skeletal age.

Limitations of cephalometry

There are various shortcomings and inaccuracies related to cephalometric analyses. These are:

1. It gives a two dimensional view of a three dimensional object.[2] It only provides a sagittal view and therefore transverse discrepancies or asymmetries in the frontal view cannot be analysed (this requires a postero-anterior cephalogram or a CBCT three dimensional analysis).[10]
2. There can be error in identification of landmarks. Thus reliability of cephalometrics comes down.
3. Errors can be made during tracing procedure.
4. Assumptions – various things are “assumed” in cephalometrics.

a. Symmetry: The various analysis done on lateral projection are based on the assumption that the patient does not have any skeletal asymmetry. In case the patient has any skeletal asymmetry then the results of the analysis may not be accurate. This can be avoided by routine study of the P.A. projection.

b. A correct occlusal and postural position is important in the accuracy of the cephalogram.

5. Fallacy of False Precision: It is found that when a person takes a series of cephalograms of the head of the same person and does the tracings, locates land marks and calculates various angles, the angles measured show a standard error that is each time the measurement is differed slightly.
6. Fallacy of ignoring the patient: The cephalometric values should not be taken as fixed goals. Sometimes certain values of a given patient may vary from the mean value, but it may not be an indication for treatment. Thus, the patient should be analyzed individually before a treatment plan. Just because the values differ it does not mean that treatment is required. If function and esthetics are satisfied then any deviation from the normal cephalometric value can be ignored.
7. Traditional cephalometric analyses and norms were based on specific populations, mainly Caucasian populations from the early to mid 1900s. This is not applicable to other ethnic/racial populations nor does it reflect changes due to secular trends. There are now numerous studies providing cephalometric norms for various populations.[10]

Analysis used in Orthodontics

- Down’s analysis
- Steiner’s analysis
- Tweeds analysis
- Mc Namara’s analysis
- Ricketts analysis
- Wits Appraisal
- Wylie analysis
- Cephalometrics for Orthognathic Surgery (COGS) for hard tissue and soft tissue
- Quadrilateral analysis
- Jarabak analysis
- Pancherz analysis
- Holdaway’s analysis
- Bjork analysis
- Sassouni’s analysis
- Analysis for anterioposterior cephalograms
- Rickets analysis
- Svanholt and Solow analysis
- Grummons analysis
- Hewitt analysis

Conclusion

Cephalometric analysis allows for the diagnosis and treatment of malocclusion, which requires an interprofessional team of dental health professionals, including but not limited to general dentists, orthodontists, and oral surgeons. Cephalometric analysis sheds light on the extent of skeletal and dental misalignments and possible causative factors. If a malocclusion is too severe to be treated by an orthodontist alone, a referral can be made for the patient to seek treatment by an oral surgeon, who can work with the orthodontist to correct the misaligned jaw utilizing orthognathic surgery, further emphasizing the need for an interprofessional approach to the diagnosis and management of complex orthodontic malocclusions. Meticulous planning and discussion with other professionals involved in managing orthodontic treatment are highly recommended to allow for successful patient outcomes.[11]

It is important to remember that meaningful data can be obtained from the headfilm and if the information is carefully applied, it can guide the clinician towards the correct treatment plan for the patient. The cephalometric morphological analysis has its limitations. Whereas it is very valuable in describing the face and permits the clinician to get an in depth understanding of where the problems are located in each individual case, it does not provide much information about future growth of the facial structures. Such information can best be provided by comparing a pre-treatment and an in treatment headfilm using a reliable superimpositioning technique.[12,13]

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