Review Article

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A View from Behind: History and Evolution of 2D and 3D Diagnostic Aids in Orthodontics

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ABSTRACT

Background: Although the evolution of three-dimensional imaging has represented a landmark in diagnostic imaging, its use in Dentistry turned out very discretely over the past few years. Three-dimensional imaging is rapidly replacing traditional radiographic methods. This new technology is particularly helpful with orthodontic concerns such as root length, bone structure, and root angulation. The use of 2D and 3D maxillofacial imaging to monitor the progress of orthodontic treatment is essential to effectively treat orthodontic patients. This review article discusses about the history and evolution of 2D and 3D diagnostic aids in orthodontics.

Keywords: Cephalometrics, cone beam computed tomography, digital radiography.

INTRODUCTION

Orthodontics is that branch of dentistry concerned with prevention, interception and correction of malocclusion and other abnormalities of the dentofacial region.[1] Earlier, the classification of malocclusion was done using dental casts. Dental casts provide the relationship of maxillary to mandibular molars and canines which helps in the assessment of the anteroposterior jaw relationship, provided the teeth are correctly positioned in the dental arches. An accurate appraisal of jaw relationship, however, can only be determined radiographically and not from dental casts alone.

Dental casts simply provide an idea of the relative anteroposterior relationship of the jaws to each other. Whether the maxilla is retrusive or protrusive cannot be ascertained from dental casts.[2] Another disadvantage of dental casts is the inability to ascertain the degree of incisor inclination. The degree of inclination of incisor teeth observed on a dental cast can be deceptive. One tends to judge the inclination of incisors by relating them to the artistic portion of the dental cast base. The inclination of incisors is thus related to the angle to which the plaster base is cut, which is not necessarily in accord with the degree of incisor inclination in the mouth. Neither the identification nor the extent of the anteroposterior jaw dysplasia or the degree of labial (or lingual) inclination of incisor teeth can be determined from a set of articulated dental casts.[2] A scientific approach to the scrutiny of human craniofacial patterns was first initiated by anthropologists and anatomists who recorded the various dimensions of ancient dry skulls. The measurement of the dry skull from osteological landmarks, called craniometry, was then applied to living subjects so that a 'longitudinal growth study' could be undertaken.

The technique of measuring the head of a living subject from the bony landmarks located by palpation or pressing through the supra-adjacent tissue - is called cephalometry. The

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word cephalometry is originated from two words, “cephalo” meaning head and “metric” meaning measurement. It was introduced in 1931 by Broadbent and Hofrath in the United States and Germany respectively. Cephalometrics is defined as a radiographic technique for abstracting the human head into a geometric scheme. It is a tool for dealing with variations in craniofacial morphology. The basic elements used in geometric analysis of cephalograms are curves, landmark points and lines. Cephalometric analysis is a collection of numbers to compress information from the cephalogram for clinical use. The application, study and interpretation of cephalograms have contributed significantly in the understanding of craniofacial growth and development, and important innovations in the diagnosis and treatment.[3]

A standardized cephalometric technique using a high powered X-ray machine and a head holder called a cephalostat or cephalometer was introduced. According to Broadbent, the patient's head was centred in the cephalostat with the superior borders of the external auditory meatus resting on the upper parts of the two ear-rods. The lowest point on the inferior bony border or the left orbit, indicated by the orbital marker, was at the level of the upper parts of the ear-rods. The nose clamp was fixed at the root of the nose to support the upper part of the face. The focus-film distance was set at 5 feet (152.4 cm), and the subject-film distance could be measured to calculate image magnification. With the two X-ray tubes at right angles to each other in the same horizontal plane, two images (lateral and posteroanterior) could be simultaneously produced.[4]

Then, in 1968, Bjork designed an X-ray cephalostat research unit with a built-in 5-inch image intensifier that enabled the position of the patient's head to be monitored on a TV screen. The patient's head position in the cephalostat was also highly reproducible.[5] Furthermore, this unit allowed the cephalometric X-ray examination of oral function on the TV screen, which could also be recorded on videotape.[6] More recently, in 1988, a multi-projection cephalometer developed for research and hospital environments was introduced by Solow and Kreiborg. This apparatus featured improved control of head position and digital exposure control as well as a number of technical operative innovations.[7]

The development of such special units, especially for roentgenocephalometric registrations of infants, has significantly contributed to the study of the growth and development of infants with craniofacial anomalies.[8] The lateral cephalometric radiograph (cephalogram) itself is the product of a two-dimensional image of the skull in lateral view, enabling the relationship between teeth, bone, soft tissue, and empty space to be scrutinized both horizontally and vertically.

It has influenced orthodontics in three major areas:

- in morphological analysis, by evaluating the sagittal and vertical relationships of dentition, facial skeleton, and soft tissue profile.
- in growth analysis, by taking two or more cephalograms at different time intervals and comparing the relative changes.
- in treatment analysis, by evaluating alterations during and after therapy.[3]

There are two distinct groups of scientifically valid analytical methods used in cephalometry: landmark techniques and boundary outline techniques. Landmark techniques are dependent on cephalometric landmarks and as such, do not depend on the form of the object they represent. Boundary outline techniques do not require cephalometric landmarks to represent the craniofacial form. As the term suggests, they only investigate the shape of the perimeter of a structure.[9]

HISTORY

Fifteenth-century saw the advent of specific measurements being made to compare the features of different skulls and head. Leonardo da Vinci (1452-1519 AD) was probably one of the earliest people of note to apply the theory of head measurement to good effect in practice. He used a variety of lines related to specific structures in the head to assist in his study of the human form. His drawings included a study of facial proportions in natural head position. According to the notes, the profile was divided into seven parts by eight horizontal lines. The subdivision is made with vertical lines. The joining of the lower lip and chin and the tip of the jaw and the upper tip of the ear with the temple forms a perfect square, and each face is half a head.[4]

Albrecht Durer (1471-1528 AC) was a brilliant, unusually productive and exuberant artist of great virtuosity. He published a treatise in 1528 on cranial measurements which comprised "Vier Bucher von menschlischer Proportion" dealing with the proper proportion of human form in the first two books, the proportions according to mathematical rules in the third book, the human figure in motion in the fourth book. Durer's four books mark a climax which the theory of proportions had never reached before or was to reach ever after.

Using strictly geometrical methods, he provided a proportionate analysis of the leptoprosopic (long) face and euryprosopic (broad) face in a coordinate system, where the horizontal and the vertical lines were drawn through the same landmarks or facial features. His drawings attest to continuous efforts to define variations in the facial morphology. One of these is significant as the key to the cephalometric analysis. The difference between the retroclined and the proclined facial profile is shown by a change of angle between the vertical and the horizontal axes of a rectangular coordinate system to characterize the facial configuration of each subject.[2]

The sixteenth-century saw the first truly scientific attempt at cranial measurement & the introduction by Spigel (1578-1625AC) of the "lineae cephalometricae". Spigel's linear cephalometricae consisted of four lines: the facial, occipital, frontal, & sincipital lines. He described these lines as follows:

• Facial: from the most inferior point of the chin to the most superior point on the forehead.

• Occipital: from the crown of the head to the atlas.

• Frontal: from one temple to the other.

• Sincipital: from the lowest part of the ear, in the region of the mastoid process, to the highest part of the sinciput, sinciput being the anterior part of the head or skull from forehead to the crown.

According to him in a well-proportioned skull, these lines should all be equal to one another. In reporting this Aitken-Meiges writes "although these lines are evidently not sufficient for the comparative ethnography, in ascending zoological scale, these lines approximate just in proportion as the head measured approaches the human form. To Spigel a skull was either well proportioned or it was not.

In 1699, a Cambridge physician, Edward Tyson (1650-1708 AD) undertook some measurements on the chimpanzee skull & proposed that there was an intermediate animal between man and monkey. He described this animal as a form of 'pygmy' but this pygmy was later shown to be another chimpanzee thereby negating his findings. The Dutchman Pieter Camper (1722- 1789 AD) was credited with the introduction of facial angle & for famous publication "Dissertation sur les varietes naturelles de la physionomie" which appeared posthumously in 1791.

The facial angle as he described it was formed by the intersection of a facial line and a horizontal plane. The facial line was a line tangential to the most prominent part of the frontal bone and to the slight convexity anterior to the upper teeth. The horizontal plane passes through the lower part of the nasal aperture, backwards along the line of the zygomatic arch, and through the centre of the external auditory meatus. Camper's facial angle was readily accepted as a standard measurement in craniology.

The drawbacks of Camper's facial angle were:

• It ignores the contribution made by the lower jaw to facial forms.

• He did not adhere strictly to his location of posterior reference point for the horizontal plane.

• The direct comparison of skull of different ages was not possible because the locating point might alter is position relevant to other bony structures with advancing age.

Shortly after this Deschamps (1740- 1824 AC) introduced the cephalic triangle made up of facial, occipital, & coronal angles. The facial angle was the lesser angle formed by the intersection of a horizontal line that passed from the external auditory meatus to the base of the nose, which crossed a profile line. This is similar to Camper's facial angle. Fortunately, the use of external auditory meatus as a reference point enabled a rough comparison to be made between different skulls. The desire to learn how men differ from each other and from animals and why, motivated several other craniologists like Doornick, Spix, Oken and many others to put forward their individual methods of analyzing human and animal skulls.

In the same period as Camper, there was a French man; Daubenton (1716-1799 AC) was very concerned with the relative position of the foramen magnum in man and lower animals. He made use of new angles, including the occipital angle to make measurements. Although his measurements were not very reliable, a similar angle was later used by another craniologist, Pierre Broca.

Daubenton's occipital angle is formed by 2 lines. the first line passes along the level of opening of the foramen magnum, from the initial edge of the foramen along the surface of the occipital condyles & anteriorly for a short distance. The second line passes from the posterior margin of the foramen magnum to the tip of the nasal spine. Broca's occipital angle was formed by two different lines giving alternative angles, originating from the posterior and anterior margins of the foramen magnum& passing anteriorly through the junction of frontal and nasal bones. The magnitude of the occipital angle decreases as the habitual posture of the animal tends more towards upright.

Daubenton's interest in the position of the foramen magnum was shared by Sir Charles Bell (1744 -1842 AC). According to him, since the head is movable on a pivot joint, it must always be balanced. Therefore the Negro skull being heavier in front & thus falling forward naturally; it is thrown backwards to poise it and relieve the muscles which support it behind.

This hypothesis was tested by a medical student, William Gibson (1788-1868 AC) in 1809 by placing in front of him Negroid &European skulls resting on their occipital condyles. Contrary to expectation, the European head fell forward and the Negroid skull fell backwards. Earlier Samuel Soemmering (1758-1826) had noted the same point in 1785.

An antagonist of Camper, Johann Friedrich Blumenbach (1752- 1840 AC) rejected the method of lines & angles as a test of national characteristics & proposed a minute survey of the skull particularly the frontal and maxillary bones. In 1795 he described a method of positioning the cranium to be measured in a standard reproducible manner. His method was simple consisting of resting the skull on its base and looking down vertically up on its vault. The points to be noted were the projection of the maxillae anterior to the frontal arch, the directions of the jaws & cheekbones (outward, forward, etc.) & the proportional breadth or narrowness of the head. He completely rejected the idea of viewing the skull in Norma lateralis.

Anders Retzius (1796-1860 AC) correlated the two schemes, i.e., of Camper and Blumenbach, thereby providing a basis for the methods of craniology used today. He is also credited with the introduction of cephalic index, the ratio of breadth to the length of the skull expressed as a percentage. John Barclay (1758-1826 AC) proposed two new angles, the superior and the inferior basic facial angles& for the first time, incorporated the mandible into his measurements. These angles were formed by the intersection of the basifacial lines with a profile line. The superior basifacial line was drawn along the basilar surface of the superior maxillary bone & the inferior basifacial line was drawn along the base of the lower jaw. The superior basifacial angle was not dissimilar to Camper's facial angle & was measured by a custom made goniometer supplied by Dr Leach.

The nineteenth century produced three great men in the history of craniology: Huxley, Broca& Topinard. Thomas Huxley (1825-1895 AC) wrote in 1876 “the so-called facial angle, in fact, does not simply express the development of the jaws in relation to the face, but is the product of two factors, a facial& a cranial, which vary independently. The face remaining the same, prognathism may be indefinitely increased, or diminished, by rotation of the frontal region of the skull, backwards or forwards, upon the anterior end of the basicranial axes”. He also introduced two new angles, the spheno maxillary and spheno ethmoidal angles. He preferred the spheno maxillary angle to Camper’s angle when comparing the degree of prognathism in different skulls. This angle is formed by the two lines drawn from basion and prosthion to prosphenion. The other angle, spheno ethmoidal, tends to be less than 180° in man.

Broca (1824-1880 AC) who is the founder of the Paris Society of Anthropology believed that the great variability of the cranial form constituted a principal difficulty for the craniologist. He was the first craniologist to institute a precise and accurate technique which could be used to compare crania so that it was made possible to discriminate between the variations in racial types among human skulls. He introduced a baseline “plan alveolo- condylien” which passes through the alveolar point & tangential to the inferior surfaces of the two occipital condyles. He also developed a craniostat, mainly constructed of wood for positioning the skull

It was generally accepted at this time that the angles were best determined on projected drawings of the skull. Broca devised a simple method to trace the outline of the skull on to a piece of paper by fixing the skull in the craniostat & positioning a drawing board with paper attached to it parallel to the midsagittal plane& a pencil held in a frame perpendicular to the paper. The resultant tracing was equivalent to a tracing of the peripheral as depicted on a lateral skull radiograph.

Paul Topinard (1830- 1912 AC) used a similar criniostat with some additional modifications. Topinard wrote in 1890 “the craniometer substitutes the mathematical data for the uncertain data founded on judgment and opinion. Moreover, it studies the skeleton of the ensemble, the skull and the face separately and each of the plates as well.

During the nineteenth century the need for standardization of methods used in craniometry became an important issue, and since then many bodies have met to better define those points and planes in use. The most important meeting as far as the dental profession is concerned was held in Frankfurt-am-Maine in August 1882. This was the 13th General Congress of the German Anthropological Society and it is to this Congress that the Frankfurt Horizontal Plane owes its name.

J.G.Garson (19th century) translated the agreement and published it in the Journal of Anthropological Institute 1885. Earlier in 1859 a horizontal plane following the zygomatic arches was suggested by a Russian craniologist, Von Baer. Later the plane was defined more precisely as a line drawn from the centre of each auditory meatus to the lower point on the inferior margin of each orbit by Von Ihering (1850-1930). The Frankfurt agreement modified Von Ihesing’s definition so that the plane passes through the upper border of the bony meatus vertically above their centres. However, the reproducibility of this plane on an intact skull is less than Broca’s condyloalveolar plane. Subsequent to the agreement the definition of the horizontal plane has been altered so that it is now taken as passing through the right and left porion & left orbitale. Thereby reducing the problems incurred by asymmetrical skulls. Following the Frankfurt Agreement, very little change of note has occurred in the definition of points and planes. In 1914 Rudolph Martin (1864-1925) published the “Lehrbuch der Anthropologie in Systematischer Darstellung mit besonderer Berucksichtigung der anthropologischen Methodoen” & this is still renowned as a fine reference book on physical anthropology.

CEPHALOMETRIC RADIOGRAPHY

In 1895, Professor William Conrad Roentgen made a remarkable contribution to the field of science with the discovery of x-rays. On December 28, 1895, he submitted a paper "On A New Kind of Rays, A Preliminary Communication" to the Wurzburg Physical Medical Society for publication in its journal.Prof. Wilhem Koening & Dr Otto Walkhoff simultaneously made the first dental radiograph in 1896.

It was clear that the use of x-rays provided the means of obtaining a different perspective on the arrangement and relation of bones, thus expanding the horizons of craniometry& cephalometry. The evolution of cephalometry in the twentieth century is universally linked to Edward angle's publication of his classification of the malocclusion. But the dogmatic inferences of the new school were criticized for failing to include differential diagnosis of facial profile in patients with class ii & class iii malocclusion.

Van Loon was a probability the first to introduce cephalometric to orthodontics when he applied anthropometric procedures in analyzing facial growth by making plaster casts of the face in to which he inserted oriented casts of the dentition. Hellman used cephalometric techniques and described their value beginning with the 1920s.

The first x-ray pictures of skull in the standard lateral view were taken by A.J.Pacini & Carrera in 1922.Pacini received a research award from the American Roentgen Ray Society for a thesis entitled "Roentgen Ray Anthropometry of the Skull". Pacini introduced a teleroentgenographic technique for standardized lateral head radiography and thereby opened, what proved to become a tremendous advance in cephalometry, as well as in measuring the growth and development of the face. His method, which was rather primitive, involved a large fixed distance from the x-ray source to the cassette. The head of the subject, placed adjacent to a standard holding the cassette, was immobilized with a gauze bandage wrapped around both the face and the cassette after the patient's midsagittal plane was carefully oriented parallel to the cassette.

He identified the following anthropometric landmarks on the roentgenogram: gonion, pogonion, nasion, and anterior nasal spine. He also located the centre of the sella turcica and the external auditory meatus.he measured the gonion angle and the degree of the maxillary protrusion.

Atkinson in 1922 advocated the use of roentgenograms in locating the 'key ridge' and the soft tissue relations to the face and the jaws. In 1923 Mc Cowen reported on profile roentgenograms that he used for orthodontic purposes to visualize the relationship between the hard and soft tissues and to note changes in profile which occur during treatment.

Simpson presented a method for obtaining profile roentgenograms in 1923 before the American society of orthodontists. In 1927 Ralph Waldron of Newark, N.J. made mention of measuring the gonion angle from a roentgenogram taken at 90 to the facial profile. Waldron was the first to construct a cephalometer, which differed little from those used today.

In 1928 Dewey and Riesner published an article, "A Radiographic Study of Facial Deformity". Dewey and Riesner immobilized the patients head in a head clamp and placed the cassette against the patient's face. They took profile roentgenograms by aligning the eye- ear plane by a right angle levelling technique. They used a target distance of three feet.

In 1931 the methodology of cephalometric radiography came to full function when B. Holly Broadbent in the USA and H. Hofrath in Germany simultaneously published methods to obtain standardized head radiographs in the Angle Orthodontist.

HOLLY BROADBENT'S CONTRIBUTION

Broadbent's interest in craniofacial growth began with his orthodontic education under E.H. Angle in 1920. He continued to pursue that interest along with his orthodontic practice, working with a leading anatomist J. Wingate Todd. The idea of diagnosing dental deformities by means of planes and angles was first proposed in 1922 by Paul Simon of Germany in his book, "Fundamental Principles of a Systematic Diagnosis of Dental Anomalies". Although his "Law of the Canines" was later disproved by Broadbent, his theories stimulated the latter to apply the principles of craniometry to living subjects.

The uncertainty of locating landmarks in the skull of the living child by approaching through the skin and soft tissues led him to search for a means of recording craniometric landmarks on the living child as accurately as done with a craniostat in measuring the dead skull. During the 1920's Broadbent refined the craniostat into craniometer by the addition of metric scales. That proved to be the first step in the evolution of craniostat into a radiographic cephalostat. It did not take him much longer to convert the direct measuring instrument into a radiographic craniometer.

Cephalometrics was neither developed as a technique looking for an application, nor was it developed as a diagnostic tool. Broadbent's single goal was the study of craniofacial growth. The Broadbent technique for cephalometric radiography was one of the tools that he developed for the implementation of that study.

The technique and apparatus perfected for the Bolton Fund study of the normal developmental growth of the face eliminated practically all of the technical difficulties encountered in previous methods of recording dentofacial changes and proved to be a convenient as well as a scientific way of measuring orthodontic procedures.

According to Broadbent, the patient's head was centred in the cephalostat with the superior borders of the external auditory meatus resting on the upper parts the two ear rods. The lowest point on the inferior bony border of the left orbit, indicated by the orbital marker, was at the level of the upper parts of the ear rods. The nose clamp was fixed at the root of the nose to support the upper part of the face. The focus film distance was set at 5 feet (152.4 cm) and the subject film distance could be measured to calculate image magnification. With the two X-ray tubes at right angles to each other in the same horizontal plane, two images (lateral & postero anterior) could be simultaneously produced.[2] While Germany's Hofrath's technique differed from Broadbent's in that the path of the central ray was not fixed in relation to the head and no plan was suggested for superpositioning subsequent x-rays.

OTHER IMPORTANT CONTRIBUTIONS MADE BY BROADBENT

In 1937, using serial records of twins; he showed how growth – or its lack – was the most significant limiting factor in clinical success. In 1943 he stipulated that eruption of the third molars had no ill effect on the denture, particularly the lower incisors.

• In 1938, a group under Allan G. Brodie at the University of Illinois presented material based on a cephalometric appraisal of orthodontic results:

1)The use of elastics causes a disturbance in the Bolton plane-occlusal plane angle;

2)Axial inclinations of orthodontically-moved teeth tend to return to their original preferences;

3)Bone changes during treatment are restricted to the alveolar process.

• Brodie, in a landmark study (1941) used for his PhD in anatomy, corroborated Broadbent's contention that the growth pattern of the normal child's face develops in an orderly fashion downward and forward and that the pattern, once attained at an early age, did not change.

• Thompson and Brodie (1942) in a report on the rest position of the mandible, concluded that:

1)The morphogenetic pattern of the head was established at a very early age and did not change;

2)The presence or absence of teeth has little, if any, bearing on the form or the rest position of the mandible; and

3)Vertical facial proportions are constant throughout life.

• Margolis (1943) wrote on the relationship between the inclination of the lower incisor and the incisor-mandibular plane angle and was the first to corroborate Tweed's clinical observation that, in normal occlusions, the lower incisors are 90° to the mandibular basal bone.

• In 1947, Wylie produced a method of assessing anteroposterior dysplasias, and, that same year, Margolis contributed his maxillo-facial triangle.[2]

Computerised cephalometry

After the development of the computerized gamma camera and computed tomography in the early 1970s, marked the first widespread application of digital imaging in dentistry . Use of digital imaging now includes computed tomography, ultrasound, nuclear medicine, magnetic resonance, and digital subtraction angiography. Digital imaging has been applied to conventional radiography, including cephalometry. Studies have been carried out comparing cephalometric digital images with their conventional radiographs with regard to image quality.[10]

Digital imaging applied to cephalometry may have several potential advantages, including:

1.automated or semi-automated cephalometric analysis;
2.reduction in radiation exposure to the patient
3.the ability to optimize image contrast and brightness
4.image enhancement archiving and improved access to image
5.image transmission;
6.super- imposition of images
7. as an -aid to surgical planning of cases.

Levy-Mandel et al. (1986)[11] developed a process for automated landmark identification. The process is divided into three basic stages:[10]

1.edge enhancement, a median-smoothing filter was used followed by a Mero-Vassy edge operator (to provide edge enhancement);

2.line extraction, a knowledge-based line-tracking algorithm was used. This compares extracted lines from the image to a model of expected lines;

3.landmark identification, from detected lines.

This system had a poor success rate unless images were of good quality. On two good quality images, 23 out of 36 landmarks were identified.

In a more extensive study by Parthasarathy et al. (1989)[12,], a different approach to Levy- Mandel et al. (1986) was used. A resolution pyramid was used to extract relevant lines in a given region using a feature recognition technique. This system located nine landmarks on five radiographs. In all, 83 per cent of the landmarks identified by the automated system were within a three-pixel radius (approximately 1 mm) of the corresponding landmark identified by two orthodontists. The system took approximately 10minutes to perform the analysis.

Tong et al. (1990)[13] suggested that the method used by Levy-Mandel et al. (1986) was mainly dependent on the quality of the original image. Tong et al. (1990) used a process of edge enhancement and thresholding, followed by edge detection techniques to identify 27 commonly used cephalometric landmarks. With this system, 17 of the 27 markers were identified as successfully, although the criteria for success was not indicated.

Previous attempts at automating cephalometric analyses failed to produce consistently good results with radiographic images of varying quality for a number of reasons. Firstly, the image operations in these systems, particularly segmentation (the extraction of image features) were not able to adapt to poor quality images. In addition, the models used as an aid to segmentation made little use of expected measurements of length, orientation and shape found on cephalometric radiographic images. Where such measurements were recorded, no attempt was made to base them on a representative sample of training images. A previous system described by Yan et al. (1986)[14] permitted the cephalometric analysis to continue even if a particular feature was not located. However, the system was unable to modify its interpretation of the image in the light of the elements found.

The system used in this study is detailed elsewhere (Davis and Taylor, 1989, 1991) but the following list summarizes the more important design aspects of the cephalometric analysis system used.

1. Cephalometric point and image feature selection.
2. Modelling the appearance and spatial organisation of cephalometric image features.
3. Spatial organisation models are used to predict image regions within which one would expect to find specific features.
4. The use of feature appearance models in finding image features (model-based segmentation) with adaptable image feature extraction methods.
5. The hierarchical organisation of cephalometric tasks.
6. Adaptive task completion behaviour, allowing difficult features to be found at a later stage.
7. Use of spatial organisation models in choosing between alternative candidates for an image feature.
8. Management of the current cephalometric task solution.
9. Display of results.

Computed tomography

The 1 st generation C.T. was invented in 1967 by Sir Godfrey N.Hounsfield, an engineer, in 1967. In this device, a single detector element was used to capture a beam of X-ray. Both detector and source rotated in a single degree that is why they were also called a "pencil" beam scanner or translaterotate. They were designed to scan the head only.

The 2nd Generation CT system was introduced in 1975; these, were also known as hybrids machines. They used more than one detector and a small fan beam; however, the image quality was poorer due to patient motion caused by the amount of time required to take the scan.

The 3rd generation CT Scanner appeared in 1976 using fluoroscopic systems, light image intensifier and a TV camera. They used a single detector element to capture a beam of X-ray. Both detector and source rotated in a single degree; thus they were also called as "Pencil beam" scanner or translate rotate.[15]

The 4 th Generation C.T. scanners replaced the arc-shaped detector with an entire circle of detectors. In this design, the X-ray tube rotates around the patient while the detector stays stationary.[16]

Recent advances in CT include multi-row electrons and spiral scanning which incorporates a moving table with rotating X-ray tube with the net effect that X-ray tube describes a helical path around the patient. Computed tomography scanners have been an active area of research due to the requirements such as contrast and special resolution.

The first Cone Beam CT (CBCT) scanner was built by Robles RA in 1982 for angiography purpose.[17] Cone beam CT scanner utilizes a two-dimensional detector which allows for a single rotation of the gentry to generate a scan compared to conventional CT scanners whose multiple slices must be stacked to obtain a complete image.

The CBCT machine called as NewTom-9000 has been developed recently in Italy by Quantitative Radiology, Verona, Italy. But it is bulky, takes 75 seconds of scan time and effective exposure of 36 seconds.

The new CBCT machine 3D Accuitomo-XYZ slice view Tomograph developed by J. Morita Mfg. Corporation, Japan is more compact (about 400kg), comparatively inexpensive and small enough to be used in dental offices, emergency rooms and intensive care units without any special adjustments.

CBCT in Orthodontics

Orthodontists routinely use 2D conventional radiographs (such as cephalometric and panoramic radiographs) to diagnose and plan treatment for patients with malocclusions and facial disproportions. However, many complex orthodontic and dentofacial orthopaedic problems require 3D analysis. To address this, CBCT has been introduced as a technique for comprehensive orthodontic imaging and for the assessment of tooth movement in all 3 planes.[3]

Although it has numerous benefits, one major concern regarding CBCT is the higher radiation dose delivered from CBCT scanners with large FOV. Therefore, the decision to conduct CBCT imaging on an orthodontic patient should be solely based on the patient's history and on the clinical examination, where CBCT should only be used if these factors indicate that CBCT is required for proper diagnosis and optimal treatment outcome. Some CBCT scanners have a small FOV, which minimizes radiation exposure; in these scanners, the number of projection images still allows for adequate visualization of the region of interest.

CBCT imaging in orthodontics is selectively indicated for the assessment of complex dentoskeletal relationships and facial esthetics, for severe skeletal discrepancies requiring orthognathic surgery, and for the assessment of the position of impacted and supernumerary teeth and their relationships to adjacent roots and other anatomical structures, thus facilitating the planning of the subsequent tooth movement.[18] Compared to 2D radiographs, CBCT imaging better facilitates the accurate determination of tooth and root length, the assessment of the minute details of root resorption, the determination of available bone width (to evaluate the buccolingual movement of teeth), the assessment of tooth inclination, the calculation of torque, and the visualization of soft tissue relationships, and it provides detailed information regarding craniofacial morphology and maxillary and mandibular changes resulting from rapid maxillary expansion.[19]

Magnetic resonance imaging

MRI is a method of using magnetic fields and radio waves in order to create an image of the body. While X-rays are still widely used to create images in order to pinpoint medical ailments in humans, MRI technology often provides more precise imaging results that help medical professionals make a more accurate assessment of a patient.

Images that are created using MRI technology result from the use of radio waves in conjunction with a magnetic field. The strength of the magnetic field is rated using a unit of measurement known as a tesla. This unit of measurement is named after Nikola Tesla, a physicist who is credited with the 1882 discovery of the rotating magnetic field.

Development of MRI

While discoveries related to magnetic fields and the use of radio waves were made prior to the development of MRI technology, Paul Lauterbur was able to develop MRI during his research of nuclear magnetic resonance (NMR). Lauterbur speculated that NMR could be used to create an image of tissue inside the human body. That image could then be studied by medical professionals in order to diagnose medical ailments. The original purpose of NMR was to study the structure of molecules, and Lauterbur is credited with being one of the first scientists to realize that NMR could be used for medical purposes.

Development of the MRI machine occurred throughout the 1970s. Lauterbur and Peter Mansfield were awarded the Nobel Prize in 2003 for their development of MRI.

The First MRI Patent

The first patent of MRI technology was filed by Raymond Damadian in 1972. The doctor and researcher discovered that images created using MRI technology could be helpful during the process of diagnosing a patient. Damadian was the first person to use MRI to make a medical diagnosis. Research completed by Damadian revealed that MRI could be used to detect cancerous tissue in animals. His patent was approved in 1974, and Damadian developed MRI for medical use by designing and building a full-body MRI machine in 1977.

MRI in orthodontics

Another form of 3-D imaging available to medical professionals is Magnetic Resonance Imaging (MRI).[20] In contrast to CBCT, MRI uses non-ionizing electromagnetic radiation. MRI allows for repetitive 3-D imaging of dental structures without potential harmful radiation exposure. MRI should be considered the first choice for pre-procedural imaging assessment for implant placement.MRI is now the gold standard for temporomandibular joint (TMJ) imaging because it is used to see the soft tissue component of the joint.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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