Panoramic Radiography

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As we broaden our concepts of bone biology, of fundamentals of occlusion, of the role of the temporomandibular joint, of nuances in mechanotherapy, has dental radiology kept pace on this expanding horizon? The answer would have to be a categoric "no", if we are limiting it to the technical quality of conventional headplates and intraoral radiographs. Recently I saw a beautiful set of intraoral radiographs that was made twenty-five years ago using the long cone technique. Magnification was minimal, pictures were sharp and there was little distortion. The orthodontist seldom sees routine dental radiographs of comparable quality today. Nonstandardized techniques, pictures taken by assistants and inadequately trained technicians yield distorted and magnified tooth morphology, roots cut completely off the film, and overlapping proximal contacts. They show nothing at all of the areas contiguous to the teeth in many instances. Because dental radiographs are generally considered to be within the sphere of service of the referring dentist, the orthodontist is reluctant to say anything and, all too often, he makes "do" and fills in the gaps from the headplate film, etc. This is hardly calculated to improve his diagnostic information and acumen. Even with properly taken dental radiographs, whether they are twelve, fourteen or sixteen compartmentalized views of the teeth, a good deal of information can be missed.

The first consideration obviously is an improvement in the taking and processing of intraoral films. The long cone technique is more difficult to use, but with standardization and careful film placement, and with precise processing procedures a great deal of improvement can be obtained. Yet, even the best intraoral films have significant limitations. The mind's eye may join individual films giving us a mental image with some continuity; but in reality, much is left out. The mechanics of film placement, film size and the limitations imposed by overlapping views, by dental morphology and the short target-film distance restrict our cumulative information to the teeth and contiguous alveolar bone, at best.

As we become increasingly aware of the importance of function and the importance of normal activity in maintaining the integrity of the stomatognathic system, we realize we need to visualize the temporomandibular joint. Yet current radiographic techniques specifically designed for TMJ radiography also are limited by distortion, superimposition, blurring, and complete lack of standardization. As a result, few temporomandibular joint films are taken routinely despite the fact that problems of bruxism, clenching, condylar displacement, etc., are frequently associated with malocclusion.

While the cephalometric headplate has been of considerable value in analyzing craniofacial and dentofacial relations, we are still primarily a "generation of profiles" as Weinstein has put it, because our reliance is almost exclusively on the lateral head film. We are taking the three dimensional object and reducing it to a flat plane. By superimposing left and right sides, both in reasonably sharp focus, we produce a

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confusing image of both buccal segments at times and, of course, the anterior segment is telescoped into an indistinguishable mass.

Right after World War II, Paatero of Finland turned to body section radiography, or tomography and laminagraphy as it is called in some fields of medicine, for better radiographic visualization of craniofacial structures.[12] It is possible to obtain a radiographic image of a particular area or layer within a three dimensional subject by carefully synchronizing the movement of the source of radiation and the film. With both the x-ray beam source and the film cassette rotating, everything else is thrown out of focus except the precise level of structures of interest to the radiologist. It is thus feasible to make laminagraphs of the thoracic cage, vertebral column or the temporomandibular joint at predetermined tissue depth levels. Contiguous and intervening structures are blurred out. Desired images are never perfectly sharp and the slight blurring effect is not completely eliminated even in the best tomographic techniques. As with cephalometric radiography, intensifying screens produce a measure of fuzziness. But it is possible to gain significant information routinely and the observer soon learns to sharpen his interpretations and to compensate for the negligible reduction in image detail.

The limitations of conventional intraoral radiography (the difficulty of film placement, gagging, and the occurrence of occasional trismus and injuries which actually prevent taking any intraoral views at all) provided ample stimulus for the development of a tomographic technique where the

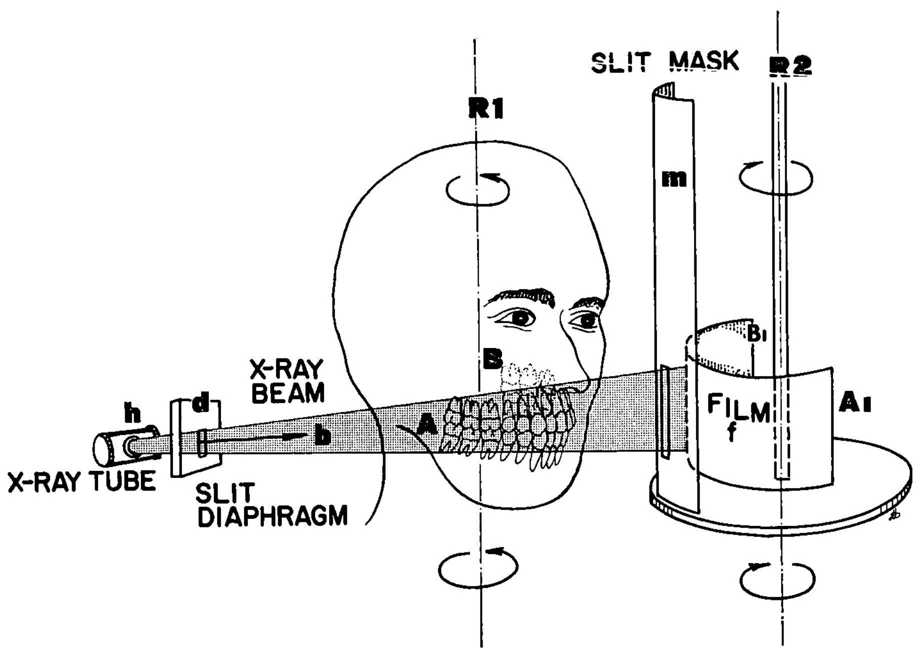

Fig. 1 Diagram of Watson Rotagraph. This is a tomographic instrument employing one center of rotation (concentric). Patient rotates on axis R1 as the curved film (f) rotates in the opposite direction on axis R2. X-ray tube (h) sends beam (b) through slit (d) to project image of patient's structures on his left side (B), so as to strike film in B1 area. With completion of rotation, beam will project structures on patient's right (A) so that they strike curved film in A1 region. (After Kumpula, J. W.)

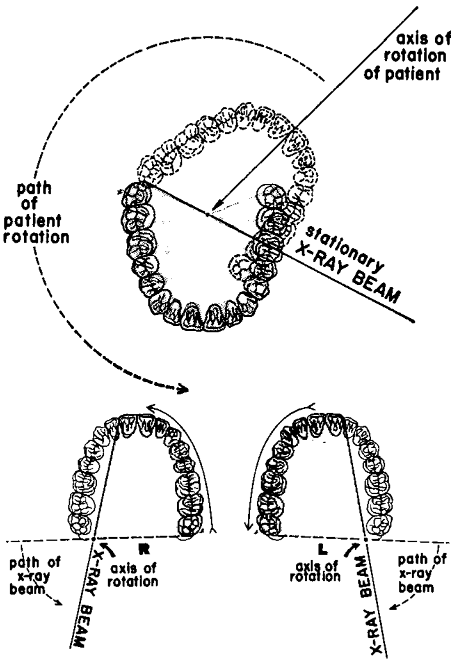

Fig. 2 above. Concentric technique diagram. Hatched area shows extent of exposure. Patient moves around stationary x-ray beam. Below. Eccentric technique diagram. Two centers of rotation just behind third molars. X-ray source moves around stationary patient. Patient shifts approximately three inches as beam reaches midline, to allow change in the rotational axis for the opposite side. (After Kumpula, J. W.)

film would remain outside the mouth and yet give a comprehensive image of the teeth and investing tissue. Paatero experimented with techniques that would produce a radiograph of curved structures rather than a flat plane or lamina. Since the dental arches form parabolic curves and not true circles, one of the problems was to make the thickness of the layer of structures in reasonably sharp focus of sufficient magnitude, or depth.

By keeping the focal spot of the radiation source as small as possible and by collimating the radiation to as narrow a slit as possible, Paatero established an optimum distance between the source of radiation and the object to keep magnification and distortion to a minimum. He obtained a depth of field of one-half to three-quarters of an inch.[3-9] The first machine that was developed consisted of a single center of rotation for both the tube and the film holder. This center was at a point just behind the third molars in the mandibular arch. Blackman of England followed the same principle and developed the Watson Rotograph (Fig. 1).[10-14] The patient rotated on one axis (R1) while the film rotated in the opposite direction on the other axis (R2) as shown in the illustration. The x-ray beam was stabilized and remained stationary. This method has proven fairly satisfactory on children and on adults with brachycephalic faces. But in dolichocephalic individuals, where the buccal segments are flat and the anterior segment is the arc of a much smaller circle, distortion and blurring frequently occur. Paatero spent eighteen months in the United States developing a prototype machine. He coined the term "pantomography" as a contraction of the words "panoramic" and "tomography".

It was apparent that the one center of rotation technique had its limitations imposed by dentofacial morphology. Instead of using the concentric technique Paatero developed a further modification using two centers of rotation, one for each side of the face (Fig. 2). Pantomograms were now being produced by an eccentric technique with the center of rotation behind the mandibular third molar on the side opposite that being radiographed. Instead of maintaining a stationary x-ray source the tube swung over from one axis to the other as it passed the midline. In the eccentric technique, both the x-ray tube and the rotating film holder moved with the patient remaining stationary.[15]

The United States Air Force and the National Bureau of Standards de-

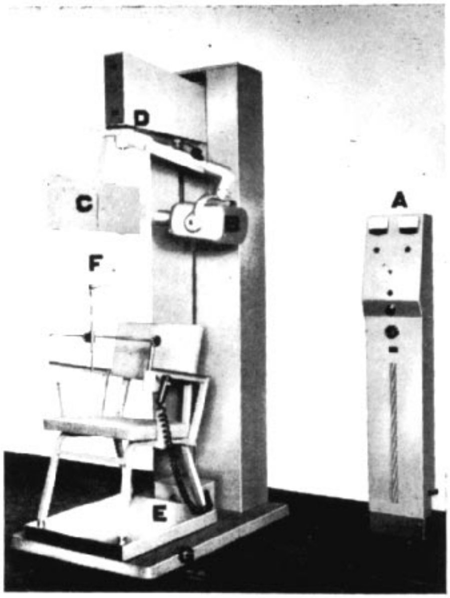

Fig. 3 Panorex tomographic instrument modeled after prototype developed by U.S. Bureau of Standards and U.S. Air Force. A. Controls and transformer. B. X-ray tube. C. Film cassette holder, with narrow exposure slit. D. Cam and cable assembly for rotating x-ray tube and film holder around stationary patient. E. Chair and base for patient. Base shifts three inches to change rotational axis when film holder and x-ray tube reach midsagittal plane in their rotational cycle. Hand control hangs on chair when not in use. F. Chin rest. G. Foot control to raise and lower exposure assembly B, C, D to fit patient in chair.

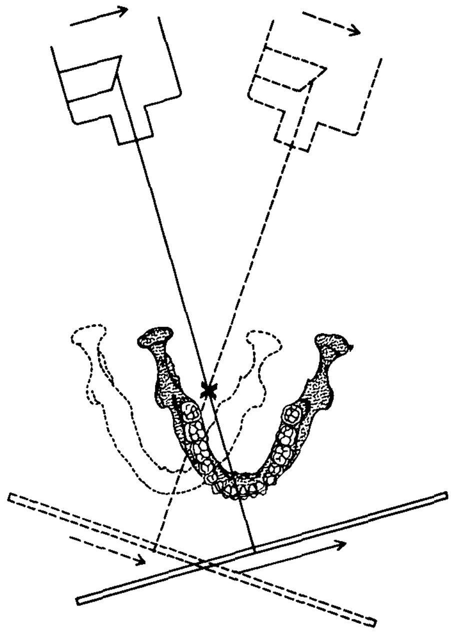

Fig. 4 Diagram after Updegrave to show mechanism of chair shift to change rotational axis for eccentric tomographic technique. Note lateral shift of patient to accomplish axis change at midsagittal plane.

veloped a panoramic dental x-ray machine for use in mass surveys around the eccentric technique principles.[16,17] This machine, the Panorex, is now being produced commercially by the S. S. White Dental Manufacturing Company and, like the Paatero original, uses one center of rotation for the right and one center of rotation for the left side (Fig. 3).[18-21] The patient is positioned with the head mounted on a chin rest while the tube and film move around him. As the tube moves around the patient, the film itself moves past a narrow exposure slit within the film holder. This exposes a different part of the film as each structure is penetrated by the rotating x-ray tube. As the x-ray tube approaches the midline, both the chair and patient shift three to four inches to get past the vertebral column and a new center of rotation is established and followed on the opposite side (Fig. 4). The movement of the tube and film holder is accomplished by means of irregularly shaped cams and cables maintaining a synchronization of the image in the film cassette. The resulting image is a panoramic picture of the dental arch and the temporomandibular joints, sinuses, etc. Since the central part of the film is blurred by the movement of the chair and the shift of rotational axis, and since there is a slight overlapping as a result of the movement, this area is usually cut out and the two films are spliced and mounted with cellulose tape (Fig. 5).

Fig. 5 Left, serial extraction case ready for fixed appliances. Note paralleling of roots of premolars and canines in maxilla. Sterile cysts indicated by arrow in mandible. Right, supernumerary tooth, lower left canine. Arch length deficiency in maxilla with upper canines and upper left second premolar impacted.

Paatero felt that there were still shortcomings with two centers of rotation in his prototype machine.[22] He saw possibilities of registering the incisor segments more faithfully, eliminating the need for splicing the film.[23] Since the parabolic curvature of the jaws is more accurately described by three arcs—the left buccal segment, the anterior segment and the right buccal segment—he developed a machine which uses a combination of the eccentric and concentric techniques with a center of rotation for each of the buccal segments and one for the anterior segments (Fig. 6). The Orthopantomograph, as it is called, has centers of rotation for the left and right sides just behind the third molar on the side opposite to that being radiographed. For the anterior segment, however, there is an additional center of rotation directly behind the incisors in the region of the premolars, anteroposteriorly (Fig. 7).

To obtain a picture with the Orthopantomograph, the patient is carefully positioned either standing or sitting, making sure that the head is not tipped and that the incisors are as perpendicular as possible. In a routine exposure the tube and synchronized film holder move as shown in Fig. 7 from position 1 to position 2 on the center of rotation "R1" providing an image of the left or the far side of the jaw on the film. At the canine eminence the tube and film holder swing to a new center of rotation, R2, and proceed to radiograph both the upper and lower anterior segments on this newly established arc. As the opposite canine eminence is reached, the center of rota-

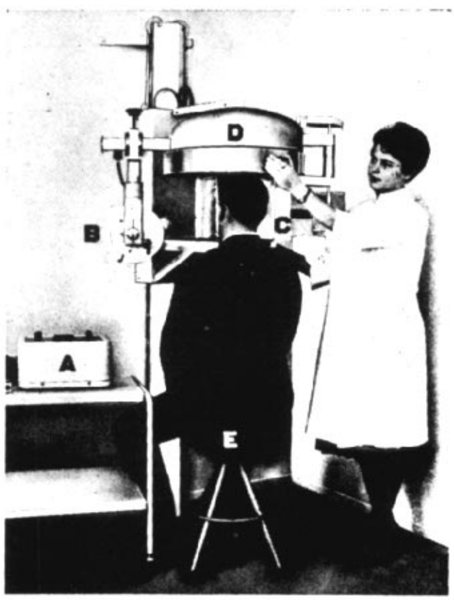

Fig. 6 Orthopantomograph using three rotational axes. A. Controls. B. X-ray tube. C. Film cassette holder. D. Motor and cam assembly for rotating x-ray tube and rotating cassette holder around the patient. E. Patient sits on ordinary stool or stands up during exposure. There is no shift at the midline.

tion changes to R3 and, using this newly established arc and center of rotation behind the lower left third molar, the right side of the dental arches is exposed. The x-ray tube rotates more than 300 degrees around the patient from one side to the other and thus exposes structures on the curved film cassette from one temporomandibular joint to the other. TMJ structures are not difficult to get on the film, even with very large heads.

Paatero,[22] Nelson,[15] Kumpula,[19] Blackman,[11] Kraske, Mazzarella[21] and others have attempted to develop equipment that gives the sharpest possible continuous image of the curved surfaces that make up the stomatognathic system. Inasmuch as the curved surfaces describe arcs of varying de-

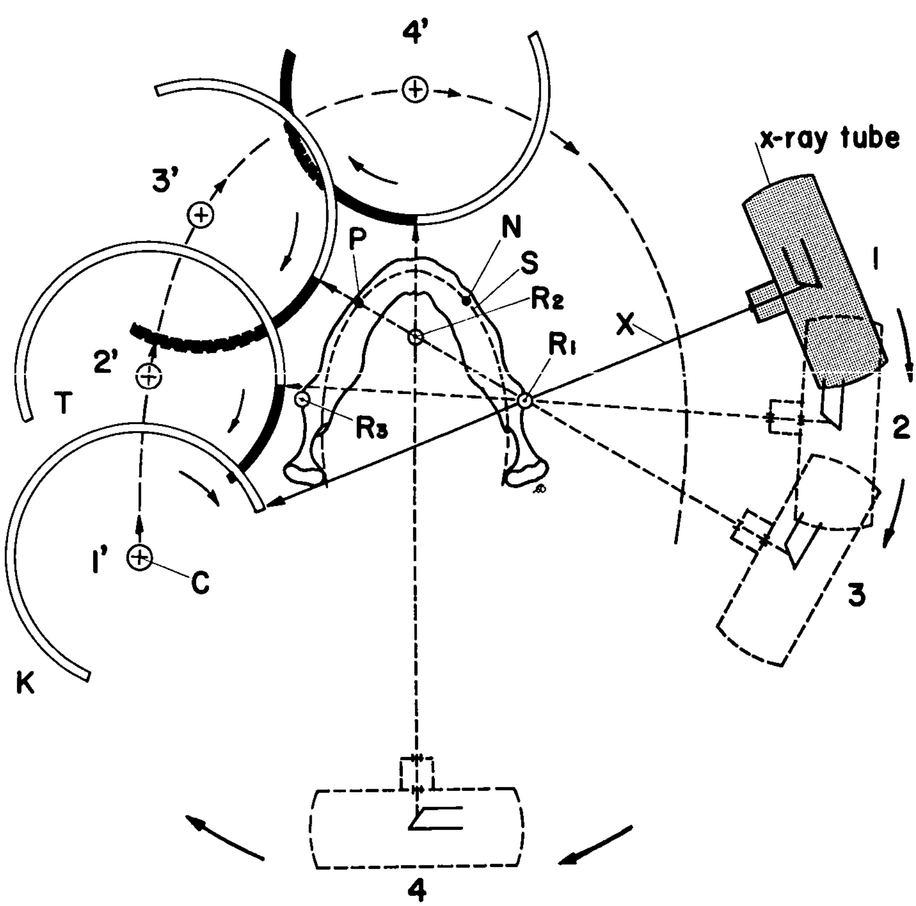

Fig. 7 Combined concentric and eccentric tomographic principle with three rotational centers; one for the left buccal segment, one for the anterior segment, one for the right buccal segment. The orthopantomograph works on this principle, changing axes in the cuspid-first bicuspid regions. The x-ray beam turns around rotational center R1 first to radiograph the left side. At the cuspid-first bicuspid region the axis changes to R2 to radiograph the anterior maxillary and mandibular portions; structures from P to N are in focus. As the beam reaches S, it swings over to R3 rotational axis and projects an image of the right side on the rotating film cassette with all structures from S to the right condyle in focus. (After Paatero)

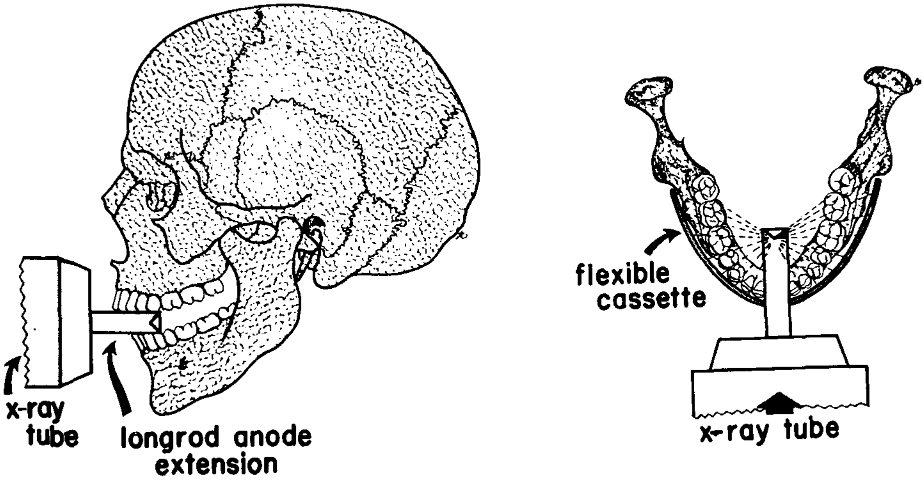

Fig. 8 Drawing after Updegrave to show tomographic technique where radiation source is in center of the mouth, and film is wrapped around face in a flexible cassette. Radiation source rotates while patient and film remain stationary.

grees from person to person, as well as within the same person, a single, one center of rotation principle is limited. The two center eccentric rotation method for the left and right side, as demonstrated in the Panorex, has been most successful but it has certain limitations which will be discussed later. The three center of rotation technique as shown by the Orthopantomograph represents one further step, combining the concentric and eccentric techniques in an effort to keep all areas sharply defined and reproduced on a single, unspliced film, but it also has its problems.

One additional type of machine is the Panagraph developed by Ott and Blackman which places the source of radiation in the center of the mouth. The film is adapted around the outside of the face in mask-like fashion (Fig. 8).[14,24] The principle utilized here is concentric but, because the source of radiation is close to the teeth and the film is also reasonably close, the distortion is reduced and the image is sharper. Magnification is more than twice the normal size, however, despite a one millimeter focal spot to keep the image sharp. The field of visualization is reduced with the third molar areas actually not showing in some instances. The temporomandibular joint is not seen at all. Other problems are excessive radiation, patient protection and greater difficulty of patient management with the anode having to be placed within the mouth. Children are more likely to rebel with the adaptation of the flexible cassette over the face.

Analysis of Panorex and Orthopantomograph

A major part of this paper is devoted to a comparison of the two most frequently used panoramic radiographic units—the eccentric, two rotational axis Panorex machine and the eccentric and concentric combination, three rotational axis Orthopantomograph. Both machines are used in our Kenilworth Dental Research Foundation and our staff has had ample opportunity to work with and appraise the relative advantages and disadvantages of the two units.

The Panorex is an automatic exposure machine with a short exposure time for any one area. The source of radiation is a ninety KVP x-ray tube with an 0.8 mm focal spot. The average target film distance varies with head size and with the region being radiographed and may range from 7 to 13½ inches. Total exposure time is 22 seconds. It requires approximately sixty seconds to position the patient properly prior to actual exposure. Ionization chambers indicate an output of 0.230 roentgens per second at a 12 inch target chamber distance. The actual x-ray beam is quite narrow and the radiation source has aluminum filtration. A routine exposure taken at 86 KVP and 8 MA exposes the patient to a total of 5.06 R. This compares most favorably with a full mouth dental examination where both the skin dose and the thyroid gland dose are many times that of the radiation emanating from the Panorex. Mitchell did a clinical study of the Panorex and wrote,[25] "It is estimated that the highest level of radiation at the skin for each Panorex exposure as made in the study would not exceed .021 R. This is less than the estimated dose to the patient resulting from a single exposure using ultra speed film. The total area of skin surface exposed at any one time during Panorex cycle is estimated at less than one square inch, whereas each intraoral exposure covers approximately six inches assuming collimation of the beam to a circle of 2.75 inches in diameter."

The fourteen to eighteen exposures required for a full mouth dental intraoral examination take considerably longer than the minute and a half needed with the Panorex. Development of the individual intraoral film is also much more time consuming. The elimination of the necessity for repeated change in x-ray tube angulation, the changing of the KVP and MA, the inserting of individual films, the need for adjustment of the different time intervals and exposure factors, the adjusting of the patient's head during the full mouth radiographic examination, the elimination of the gagging and discomfort from placing films within the mouth, etc., are major advantages for the Panorex. To offset these advantages is the fact that the routine panoramic films do not always have the same degree of sharpness in various parts of the mouth. The "focal trough" or the area in which the image is reasonably sharp in detail is relatively narrow, one-half to three-quarters of an inch, and variations in dentofacial morphology can and do result in some areas being indistinct because they lie outside the focal trough or the arc around the rotational axes.

A further limiting factor is the need for intensifying screens with panoramic radiograph techniques, even as they are used for cephalometric radiography. This reduces the sharpness of the resulting image when compared to a nonscreen film.

With the Panorex there are in reality two exposures, one for each rotational axis or one for each side of the head with the center part of the film blurred as the chair and patient shift in the actual change of axis. The shift of three to four inches past the vertebral column does not eliminate the visualization of the anterior structures, since there is an overlapping at this area. Even with the entire blurred portion cut out, all the structures are present and reasonably sharp on the film when the two separate halves are mounted together again (Fig. 5). However, because of the eccentric rotational axes the lower incisors often do not appear in true profile and seem to slant toward the midline with a certain degree of distortion. There is also a tendency to foreshorten the roots depending on the axial inclination of these teeth. No matter how carefully one tries to cut the film at the midline to get the maxillary incisors in their proper relationship, there always seems to be from one-half to one extra tooth at the midline of the lower arch because of the distortion. This may be eliminated by positioning the head with the long axes of the lower incisors vertical, raising the head in the head holder, and taking another film. Then the maxillary incisors show more distortion. This is a definite limitation of the Panorex, but the observer soon learns to recognize the problem and can augment the panoramic examination with some extra intraoral views or go back to the patient and casts and check actual lower anterior tooth position. While the Panorex does not produce as symmetrical a projection of the teeth and supporting structures as made by the concentric technique where there is one center of rotation, it certainly does make a sharper and more accurate projection of the buccal segments.

The Orthopantomograph with its combination of the concentric and eccentric rotational axes for the radiation source and film holding cassette eliminates the shift of the dental chair and the imperfect representation of mandibular incisor teeth. Instead of taking two exposures and cutting out the blurred portion of the film as is done on the Panorex, the Orthopantomograph carries through with one single exposure and no need for splicing. The entire cycle is completed with a shift in rotational axis at approximately the first bicuspid region on each side. As with the Panorex the posterior axes are behind the third molar teeth. It is a technical challenge to shift the rotational axis twice during actual exposure and still maintain a smooth, constant and progressive exposure of the film. The discerning radiologist can often pick up the point of axis change because of a narrow band of fuzziness in the bicuspid region.

The exposure cycle of the Orthopantomograph is only fifteen seconds as compared with twenty-two seconds for the Panorex. A shorter exposure time reduces the likelihood of patient movement and cuts down the amount of radiation. Radiation is no problem, however, since the Panorex is well below what it would take for an ordinary full mouth set of intraoral radiographs (which are within a safe tolerance by themselves). The Orthopantomograph is one-third less than the Panorex. The focal spot of the source of radiation for the Orthopantomograph is the same size as the Panorex giving a relatively sharp image. The exposure factors are also similar, 80 to 86 KVP, but with a slightly greater milliamperage to make up for the shorter exposure time, 15 to 20 milliamps.

With the Orthopantomograph the problems of magnification and distortion are of greater concern. Because of the larger object-film distance in certain areas, the magnification of the incisors, for example, is more noticeable than in films taken with the Panorex machine. Patient positioning is more critical if the best possible image is to be obtained. The incisor teeth must be as vertical as possible and even minimal tipping of the head in the head holder produces significant distortion on the film. But if patient positioning is correct, the unbroken panoramic view of the stomatognathic system from one temporomandibular joint around to the opposite temporomandibular joint is a fine spectacle, indeed (Fig. 9).

There is increasing emphasis on the role of the temporomandibular joint in disturbances of occlusion, in bruxism, functional disturbances, etc. Both the Panorex and Orthopantomograph give good profile views of the condyle and the articular eminence on each side, but the Orthopantomograph does have a special viewing position which moves

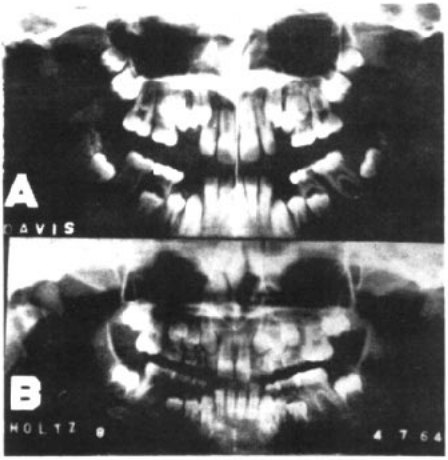

Fig. 9 Panoramic radiographs taken with Panorex (A) and Orthopantomograph (B) during mixed dentition. Problems of space adequacy, tooth size, root resorption, direction of eruption, status of third molars, etc., are visualized with the aid of panoramic radiography. Such records are particularly valuable for serial extraction.

the head forward and gives usually good and reproducible profile representations of the condyle and contiguous structures. Various functional positions and relationships of the condyle, disk and articular eminence can be produced rather precisely with this technique. A superior visualization of the temporomandibular joint is achieved with a laminagraphic technique, since the intervening structures do not show because of the tomographic process. With conventional radiography the superimposition of the mastoid air cells, the temporal bone, the pterygoid plates, etc., frequently make radiographs of the temporomandibular joint difficult to interpret or reproduce.

Advantages of Panoramic Radiography

1. Comfort. The patient must remain immobile, but the head is maintained in a natural, erect position and supported so that movement should be no problem. No actual films are inserted in the mouth. The actual time exposure is only fifteen seconds for the Orthopantomograph and twenty-two seconds for the Panorex. The total time of positioning the patient and making the exposure should not exceed a minute and a half. In younger children this is quite an advantage.

2. Ease of operation. Difficult patients, apprehensive children, patients who gag easily, patients with trismus or with jaw fractures preventing movement of the mandible, or edentulous patients find panoramic examination much easier. In some instances routine intraoral radiographic examination would be impossible.

3. Less total radiation. The total amount of exposure remains well below that required for a conventional full mouth intraoral examination. Selected intraoral views may still be taken to corroborate or amplify information gained from the panoramic film and the total exposure time still is not a matter of concern.

4. Additional information may be gained that would not be available from intraoral or cephalometric radiographic examination. Cysts, neoplasms, supernumerary teeth, congenitally absent teeth, impactions, abnormal eruptive directions, proximity of the sinuses, position of the mandibular canal, relative state of root formation, etc., may be seen readily with panoramic radiographs. The temporomandibular joint and mandibular morphology, as well as the maxillary sinuses and mastoid air cell region, show up remarkably well.

Disadvantages of Panoramic Radiography

1. For precise information on dental caries and on the periodontal membrane, the panoramic radiograph is no substitute for properly taken intraoral radiographs. Tomographic processes,

plus the use of intensifying screens, do not give as sharp an image as that of the conventional intraoral dental film. Newer films, better screens and other technical improvements may provide a better panoramic image, but at present it does not compare with that of a well-made dental radiograph. This does not mean that diagnostic information is not available, because most carious lesions can be seen on panoramic radiographs, as well as areas of bone loss, calculus deposits, the periodontal membrane, etc., but it is frequently advisable to make substantiative spot intraoral films to corroborate the information gained from the panoramic radiograph. A good routine combination would be a panoramic radiograph plus a set of bite wing films for the right and left buccal segments.

2. The lower incisor region is not properly reproduced in the Panorex film. Some overlapping is a result of the shifting of the dental chair and the two-axis eccentric approach. When the blurred central portion is spliced out, there is still a half-tooth extra in the lower anterior segment as a result of the splice, if the maxillary central incisors are to be related properly. In addition, the inclination of the lower incisors is usually slanted with the crowns mesially inclined. An additional view, with the head tipped up and the lower incisors perpendicular to the central ray or parallel to the film surface, largely eliminates this tendency, but then the upper incisors become distorted. Two views are to be recommended where both upper and lower incisor information is to be desired. For routine surveys, however, one conventional view with the long axes of the maxillary incisors parallel to the film will suffice. Where there is an anterior supernumerary tooth expected, it is sometimes better not to splice out the blurred central section, but to make the interpretation from the intact film.

The Orthopantomograph does not have the problem in the incisal area since the continuity of film is unbroken from condyle to condyle. More precise positioning is required, however, with the Orthopantomograph. Distortion is more readily seen and there are times when the first premolar area produces an image of less than satisfactory diagnostic value because of the change in rotational axis on each side of the head at this point. Our experiences with the Orthopantomograph and Panorex show that the image is not quite as sharp in the buccal segments with the Orthopantomograph as with the Panorex. This also may be eliminated through technical improvements but at present this feature is a definite disadvantage. Thus the buccal segments with the Panorex are superior; the lower anterior segment is usually better with the Orthopantomograph. Magnification and distortion are greater with the Orthopantomograph than with the Panorex.

3. Expense of the original equipment is considerably greater than with conventional dental x-ray machines. It is not possible to make routine dental radiographs so it is not a substitute for intraoral x-ray equipment.

4. Panoramic radiographic equipment is comparatively more bulky than the dental x-ray machine. While the Panorex equipment uses more floor space than the Orthopantomograph which is mounted primarily on the wall, this is not enough greater to make any appreciable difference. It is well to think of having a separate room for either piece of equipment, however, because of the space requirements.

5. Not all head shapes produce the best possible pictures. More than three years of extensive use and experimentation indicate that varying jaw and arch morphology produces pictures of varying diagnostic value. A very large or

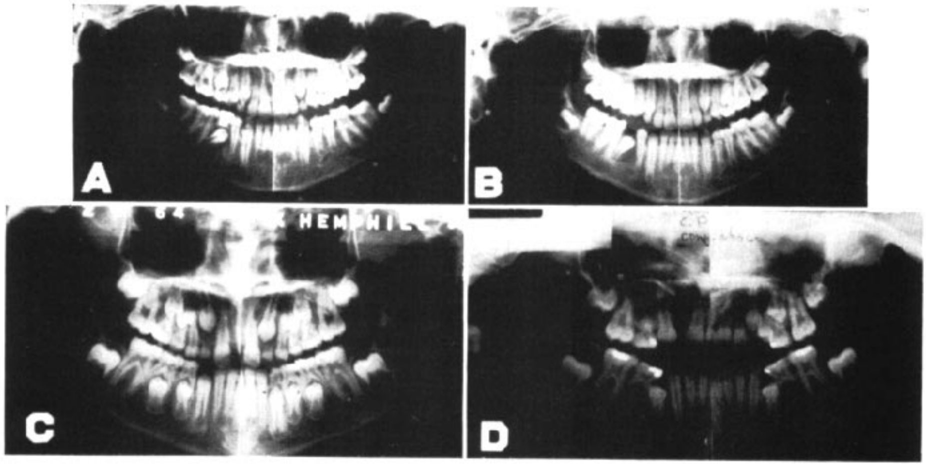

Fig. 10 A. Cyst around lower left second deciduous molar, involving second bicuspid. B. Same case after removal of cyst, showing eruptive progress of second bicuspid. C. Congenital absence of maxillary lateral incisors. D. Cleft palate, congenital absence and serial extraction problem. Removal of upper right first premolar, lower second deciduous molars to correct arch length deficiency and mandibular prognathism is indicated.

small head with the dental structures falling outside the one-half to three-quarters of an inch depth of reasonably sharp focus will appear blurred or distorted.

Use of the Panoramic Radiography

1. Growth and Development. Orthodontists are familiar with the uses of cephalometric radiography and it is not necessary to stress the importance of knowing the normal growth and developmental pattern, and the necessity for recognition of departures from the normal pattern. Since we are superimposing both left and right sides on a cephalometric film, it is sometimes difficult to obtain precise information from the cephalogram. Panoramic radiography is of significant value in helping the orthodontist visualize the status quo with negligible problems of superimposition. Delayed tooth eruption, abnormal eruptive direction, and abnormal resorption, supernumerary teeth, cysts, congenitally absent teeth, ankylosis, prolonged retention, density of bone, distance from apices to mandibular border, axial inclination, space adequacy are just a few of the clinical entities of concern to the orthodontist that may be reliably visualized through panoramic radiography (Figs. 5, 10, 11). This is of particular concern during the mixed dentition period and thus makes the periodic panoramic examination a good pretreatment observation record.

2. The Temporomandibular Joint. A number of radiographic techniques have been introduced to visualize the temporomandibular joint. Articles by Lindblom,[26] Lewis,[27] Grewcock,[28] Gillis,[29] McQueen[30] and Updegrave[20] have attempted to describe techniques which provide the best possible radiographic image of this all-important functional region. Yet the panoramic radiograph, and particularly the Orthopantomograph, provides a sharp and accurate profile view of the condyle, of the articular eminence and of the articular fossa itself. Not infrequently the articular disc may be seen. The resultant views from panoramic radio-

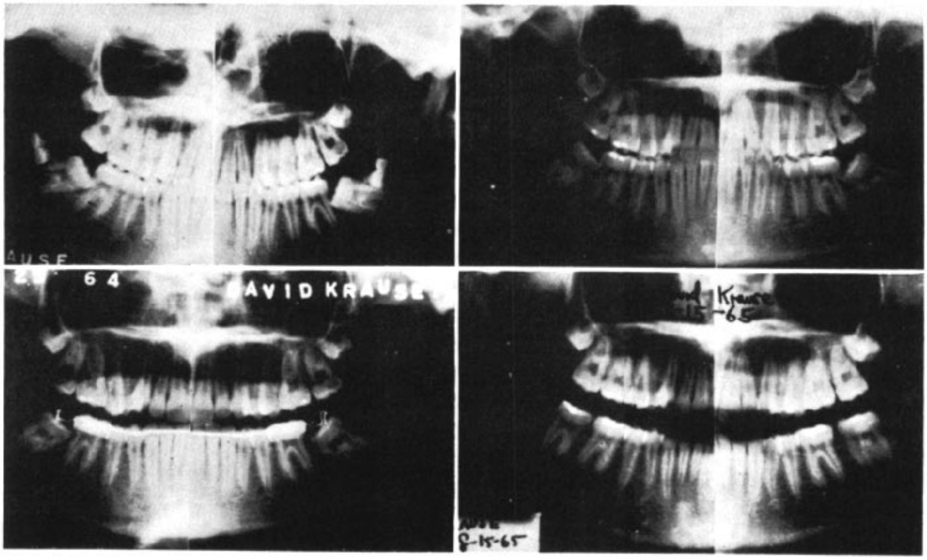

Fig. 11 Progress reports in case where mandibular second and third molars were impacted. Third molars were removed and second molars were tipped distally with simple appliance.

graphy are superior in most instances to those obtained by so-called "special" views. Because of the frequency of temporomandibular joint involvement in Class II, Division 1 and Division 2 malocclusions, because of the changing condylar position with respect to the degree of overbite, because of the problems of bruxism, clenching, crepitus, etc., the orthodontist should be prepared to obtain diagnostic and prognostic information of this center of stomatognathic function (Fig. 12).

3. Sinuses and Mastoid Region. All too frequently the dentist is confronted with pains of obscure origin, attributable by the patient to the teeth, but with no corroborative dental evidence. In many instances the focus of infection and accompanying pain may be attributed to the maxillary sinuses. In addition, the sinuses have frequently been perforated by root tips or parts of teeth because of their proximity to the maxillary sinus. The difficulty in removing these teeth without sinus involvement is obvious. Accurate radio-

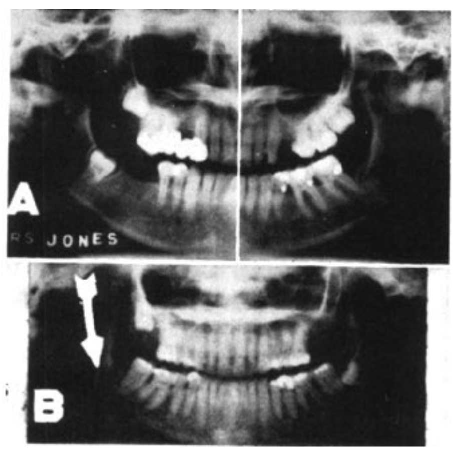

Fig. 12 A. Young adult with Class III malocclusion, missing teeth, temporomandibular disturbance and impacted third molars on the right side. All aspects of the problem are seen on a single panoramic view, and the surgeon has a precise outline of mandibular morphology in event he wishes to perform a resection. B. Comminuted mandibular fracture, radiographed without patient opening the mouth. The extent of surgical challenge is readily apparent.

graphic views of the proximity of the sinuses to the dental structures is of significant value. Although this information is of more immediate use to the oral surgeon and general dentist than to the orthodontist, such information should form a part of the initial orthodontic examination and should be made available to the patient. The unusually good pictures obtained of the sinuses are possible because of the tomographic process which eliminates intervening structures (Fig. 9).

4. Mandibular Morphology and Fractures. Accurate views of mandibular morphology are produced by the panoramic radiographic technique. Cephalometric radiographs do this reasonably well for the buccal segments, but the left and right sides are projected on the same plane and the area mesial to the cuspid is usually lost and of no diagnostic value. For Class III malocclusions with resections a definite therapeutic possibility, the shape of the mandible is most important. There is less need for the so-called "blind" operation with panoramic radiographs. The surgeon can determine in advance the shape and relations of the mandible and its associated structures. He may also appraise the relative success and posttreatment response to his endeavors through a longitudinal series of panoramic radiographs. There is no need to depend on cephalometric radiographs and nonstandardized and nonoriented lateral jaw films which give him only a part of the picture, and a distorted part of it at that.

It is particularly important that an accurate picture be obtained where there has been a jaw fracture or suspected jaw fracture (Fig. 12B). In such instances where the parts cannot be moved, the panoramic radiographs provide valuable and precise data on site and extent of fracture, comminution, etc. After surgical reduction of the fracture, continued panoramic study will reveal the apposition of parts, sloughing, healing progress and bone density, as well as any change in tooth position.

5. Pathology. As indicated in the discussion under growth and development, it is important to know the normal and to intercept the incipient abnormalities that might prevent the accomplishment of a normal pattern. Any conditions that cannot be prevented should be recognized as early as possible. Only then can the proper therapeutic measures be undertaken. Cysts, neoplasms, supernumerary teeth, congenitally absent teeth, trismus, impactions, ankylosis, abnormal retention and premature tooth loss, abnormally eruptive path, abnormal resorption, improper restorations, overhanging margins and periodontal pathosis are seen quite well in routine panoramic radiographs. Longitudinal study provides comparative postoperative records which are as important or more important than the original, pretherapeutic views.

6. Space Adequacy. Inasmuch as a significant number of patients in orthodontic practice have Class I malocclusions characterized by generalized crowding and rotations, individual tooth malpositions, presence or absence of third molars, etc., and since it is important to know quite early whether there will be sufficient space available ultimately to accommodate the teeth in a normal and stable relationship, diagnostic information should be obtained as early as possible. Such information may be found in the routine panoramic films. Nance,[31] Kjellgren,[32] Hotz,[33] Heath,[34] Mayne[35] and Dewel[36] have shown dramatic results from planned programs of serial extraction. Early removal of deciduous teeth and possible removal of first premolars may allow considerable autonomous adjustment with a major improvement in

tooth positions and a reduction of the therapeutic challenge both from an appliance and time standpoint. The measurement of teeth from casts and on the patient and the attempted measurement of the width of unerupted teeth on dental or intraoral films are not always satisfactory. Panoramic radiographs show the entire dentition at a glance. Magnification is relatively constant and measurements can be made with a fair degree of accuracy. Equally important, the precise relationship of the deciduous and permanent teeth and the paths of eruption are literally discernible.

Much harm can be done from improperly diagnosed serial extraction cases. It is vital that all this information be available *before* such a program is instituted. Periodic panoramic examinations are recommended to show the progress of serial extraction cases (Figs. 13, 14). Too often the third molars and their relative development and position have been overlooked. Yet they are part of the picture of serial extraction and should be considered in the total analysis of adequacy of space. We have not resolved the controversy of the role of third molars in posttreatment adjustment, but we do know that if it is a decision of "four teeth now or four teeth later", and if the third molars are in good position, it does not make the best orthodontic sense to struggle to increase arch length for four bicuspids, to lose it partially through relapse and then to remove four third molars which would have erupted normally with the removal of the first bicuspids and would serve as important functional units.

Three years of study of panoramic films indicates that the percentage of congenital absence of one or more third molars is surprisingly high. In 328 films of patients below sixteen years of age, there is congenital absence in the third molar region in 17.9 per cent. Before embarking on a planned program of progressive extraction for arch length deficiency, before removing dental units to provide space which may be available due to the congenital absence of third molars, a panoramic radiograph may be taken to serve as the basis for a differential diagnosis.

7. Treatment Progress and Posttreatment Appraisal. The changes wrought by mechanotherapy are not difficult to discern at each visit if the orthodontist confines his judgment to the clinical crowns of the teeth. But what is going on in the alveolar process is another matter. Few dentists take routine intraoral radiographs during treatment and most dentists are reluctant because, "there is little to see when the bands are in place." If the dentist is looking only for caries, he may be correct, but there is much more to be seen "of the iceberg under the water." Particularly, with the potent light wire techniques which produce rapid tooth movement, it is imperative to see the the tissue response. The thickness of the periodontal membrane, the paralleling of roots next to extraction sites, the eruption of teeth not clinically present, avoidance of excessive tipping and early detection of the integrity of the alveolar crest, the amount of root resorption and obvious carious lesions are examples of information that each orthodontist should have during treatment of every case. The decision to extract or not to extract can be borderline. Tooth position changes during treatment, plus a panoramic radiograph to determine the status quo will facilitate a decision in the right direction (Fig. 13). Treatment plans frequently should be altered for the patient's benefit. With "x-ray eyes" the progress toward ultimate therapeutic success is likely to be more rapid and more successful.

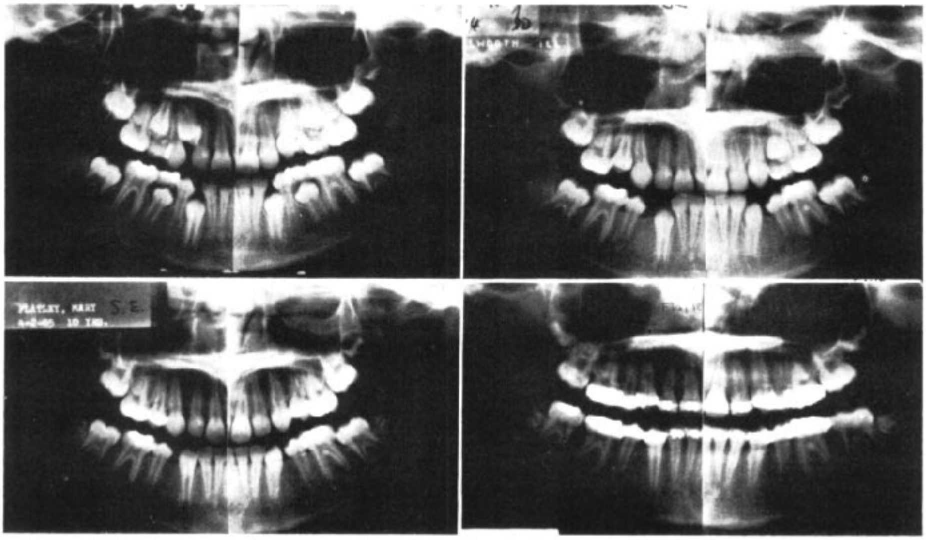

Fig. 13 Arch length deficiency and transposition; upper left canine and first premolar. First premolars were removed (upper right) with canines erupting into occlusion (lower left). Fixed appliances are being employed to complete therapy. (lower right)

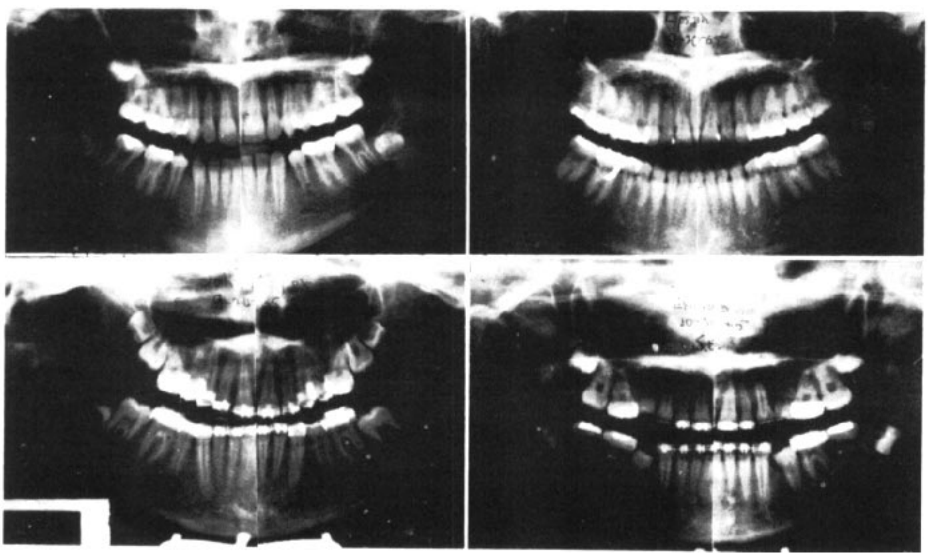

Fig. 14 Serial extraction cases. Upper left, ready for a short period of mechanotherapy. Upper right, serial extraction upper arch only with removal of mandibular third molars prior to eruption. Lower views, progress panoramic radiographs during active treatment.

It is not necessary to belabor the point that retrogressive changes occur too frequently following removal of orthodontic appliances. Posttreatment observation should include more than a cursory examination of the meeting of the inclined planes. A study of incipient rotations and an awareness of increasing crowding in the lower anterior segment are indicated. Routine panoramic radiographic examinations will show the progress of eruption of third molars, if they are present, the continuity of bony tissue around the teeth, the status of the periodontal membrane, the maintenance of axial inclinations, etc. The need for occlusal equilibration or possibly further therapy may be partly determined with the help of panoramic radiographs.[37]

Summary

Several techniques have been developed to provide panoramic views of the teeth and contiguous tissues on a single extraoral film. These techniques employ tomography, or body section radiography, literally taking a one-half to two-thirds inch slice around the dental arches and associated structures. This trough is in reasonably sharp focus, while all other intervening structures are blurred out of focus by the moving tube and film cassette. The greater target-object film distance, the use of intensifying screens, and the large amount of secondary radiation to provide the image make the picture less distinct than the conventional dental radiographs despite the small focal spot of 0.8 mm. Properly taken panoramic radiographs, however, have sufficient diagnostic value to be used routinely in conjunction with spot dental radiographs to confirm diagnostic impressions made from the panoramic radiograph. A routine combination of a panoramic radiograph and bitewing radiographs offers the best diagnostic package. It supplies considerably more information than routine intraoral periapical radiographs.

Panoramic radiography is a useful diagnostic tool in studying growth and development, resorption and eruption patterns, the temporomandibular joint, the sinuses and mastoid regions, mandibular morphology and fractures, and various pathological conditions such as neoplasms, cysts, supernumerary teeth, ankylosis, abnormal eruption and so forth. Panoramic radiography is also of significant value in serial extraction procedures and progress reports during therapy.

Two of the machines now in use (S. S. White Panorex, Siemens Orthopantomograph) are compared. The Panorex, with its eccentric, two centers of rotation and two cam adjustment permitting adult and child views, produces uniformly good, accurate pictures of the buccal segments and maxillary anterior teeth. The mandibular incisors are less accurate though diagnostically acceptable. The film must be spliced in the center, however, cutting out the portion that is blurred by a shift of the chair midway during the exposure.

The Orthopantomograph provides a continuous image on a single film with no need to cut and splice. Patient positioning factors are more critical, however, and there is a tendency to lose some information with the change of rotational axis. Since the Orthopantomograph uses three centers of rotation, instead of two, the changeover point at the first bicuspid region may show a lack of definition. Unlike the Panorex, no provision is made for a child or adult head as far as a variable "focal trough" is concerned.

The significant amount of diagnostic information routinely available, the short exposure time, the relatively low amount of radiation and optimum patient comfort make this equipment a desirable addition to the orthodontist's

diagnostic tools. The high initial cost, the greater space requirements, the need for occasional selected and confirmatory intraoral dental radiographs must also be considered in a truly objective appraisal.

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