Periodontal Tissue Response to Orthodontic Treatment Studied by Panoramix

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Orthodontic therapy is generally based on the assumption that the response of the periodontal tissues to orthodontic mechanisms is physiologic. The reaction of these tissues to orthodontic tooth movement has been studied throughout the history of modern orthodontics. These studies have been either histologic or radiographic. Up to this time they have failed to give us concrete evidence as to the ultimate periodontal health of patients following orthodontic treatment. Some periodontists have indicated that they feel that orthodontic treatment may be one of the etiologic factors in the development of periodontal disease in later years. This implies that orthodontic tooth movement is destructive to the investing tissues of the teeth. Orthodontists have held that physiologic tooth movement with an orthodontic appliance is probable. When there has been evidence of periodontal damage following orthodontic tooth movement, it has been believed that there has been some misapplication of force, either in intensity, direction or duration. We have by no means established the physiologic limits of forces applied orthodontically. It is the purpose of the present study to investigate radiographically on a longitudinal, long-term basis the responses of alveolar bone, periodontal membrane, and cementum to orthodontic pressures. Employment of the Westinghouse Panoramix machine combined with a head-stabilizing technique allows for a superpositioning similar to that used in cephalometric studies. This, it is hoped, will provide accurate measurement of the effect of orthodontic pressures on periodontal structures. Dental intraoral radiography has been unable to supply these accurate data because of the difficulty in stabilization and longitudinal reproduction. Cephalometric films have not been usable for this purpose because of the dual imposition of lateral structures. The Panoramix machine projects its rays from within the oral cavity outward eliminating the dual imposition. It also provides detailed roentgenograms of bone, periodontal membrane spaces and dental hard tissues. The purpose of this report is to study, in detail, changes in these structures, incident to and following orthodontic tooth movement. Secondarily, it is hoped to observe and accurately measure tooth movement in order to evaluate the effectiveness of various orthodontic mechanisms and the response of the periodontal tissues. The intent is to pursue this study over several years to gain information on the permanent effects of such treatment.

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Review of the Literature

The early investigations into the tissue reaction to orthodontic forces were histologic, generally on animal material. Sandstedt,[1] Schwarz,[2] and Oppenheim[3] pointed out the mechanism of cellular response to orthodontic pressures. These studies are the groundwork of our present understanding of histologic change. Basically they found that lighter forces produced surface resorptions of the alveolar cribriform plate by osteoclastic activity on the pressure side and osteoblastic activity on the tension area forming osteoid and new bone. Heavier forces (Schwarz maintained those in excess of capillary pressure) produced cell-free or hyalinized areas in the periodontal membrane region. These regions serve as mechanical barriers to further tooth movement and could only be removed by cellular elements mobilized from within the narrow spaces. The implication was that the light forces produced surface resorptions which was the physiologic response and less destructive to supporting tissues. Heavier pressures produced cell-free areas, undermining resorptions, and tended to produce damage. Reitan[4] has elaborated on these early studies and provided extensive details of tissue response on human and animal material. His approach also has been primarily histologic. Histologic studies, although revealing valuable information, have the definite limitation of representing a single moment in the course of treatment. Jarabak[5] has provided in his text extensive and detailed intraoral roentgenographic serial material on tissue reactions. Baxter[6] in an intraoral serial study measured alveolar crest heights in extraction cases in the area of the extractions. He found no significant loss of crest height during space closure and orthodontic treatment. The approach of this study represents the first attempt at a valid roentgenographic superpositioning technique using intraoral radiography.

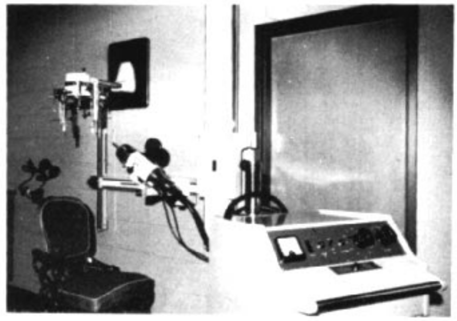


Fig. 1 Panoramix equipment and cephalostat.

Methods and Materials

The x-ray machine used in this study is the Westinghouse Panoramix. It is able to produce in one exposure a picture of a complete arch by placing the anode stem intraorally (Fig. 1). The tube emits radiation in a 270 degree arc in two perpendicular planes. In function the radiation emerges from a miniature anode 100 micron sq. mounted at the tip of a copper cone. The anode stem is placed inside the mouth with the film placed around the face. The geometrical relationship of the anode—object and film is such that distortion and magnification of the image occurs; they are unavoidable in a complete radiograph. These factors will be considered later in more detail. Radiation dosage to the patient is considerably less than that of a periapical intraoral series of the maxillary arch. Collimation is utilized by covering portions of the tube with lead to avoid unnecessary radiation to the tissues not involved in producing the radiograph.

The head positioner employed in conjunction with the Panoramix machine is a modified Wehmer cephalo-

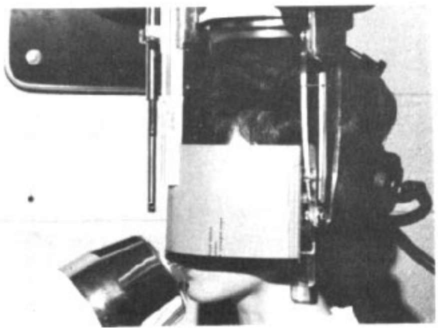


Fig. 2 Patient stabilized in cephalostat, film and tube in position.

stat. The tube is positioned in the midline of the cephalometer and fixed at a 30 degree angle. This midline position is critical and any slight deviation produces considerable bilateral asymmetry of the radiographic projection. The head is attached to an arm machined to track horizontally and vertically by geared mechanism. Both of these measurements are calibrated with millimetric rulers attached and readings are obtained for each patient. These readings may then be reproduced for positioning of subsequent films (Fig. 2). The patient is placed in the headholder and the ear rods fixed. This measurement is read from the scale on the rear of the cephalostat. In earlier films the patient was positioned with the Frankfort Horizontal plane parallel to the floor using the usual orbitale pointer. The head was fixed by the vertical nasion holder. However, it was found that because of the divergence of the occlusal plane relative to the Frankfort plane, the molars were at a higher level than the incisors. This produced a curved occlusal plane on the films with increased distortion in the molar area particularly in smaller arches. The technique has subsequently been modified by measuring the divergence of the Frankfort plane from the occlusal plane, then the orbitale pointer is calibrated so that the head can be positioned with the occlusal plane horizontal. The following measurements are recorded for each patient: porion or ear-rod distance taken from the scale on the rear of the headholder, vertical and horizontal tube positions, *Vn* or vertical nasion and *Hn* or horizontal nasion, taken from the scales on the nasion holder. Vertical and horizontal tube positions are read from scales on the calibrated wellmount of the head. The last two measurements are obtained after the anode has been placed in the patient's mouth.

The radiographic film selected consists of one-half of an 8 x 10 Kodak no screen ready pack. The 4 x 10 film is then secured in the midline in a slot in the nasion holder and the ends are attached to two slotted plastic receptacles fastened to the ear rod uprights. The film is secured under tension so that it conforms to the same shape for each exposure. Calibrations are recorded for each patient and then reproduced for subsequent exposures. This technique has been unable to consistently reproduce the accuracy on serial films necessary for valid measurements of tooth movement. Anode-object distance is so short and the angle so great that any small variation in position produces magnification distortions beyond acceptable superpositioning reliability. As in any new technique, difficulties and limitations not anticipated when the study was undertaken have been encountered. The primary problem with the technique has been the high target-object angle. This limitation is inherent in the machine because the anode must be placed within the arch. Even the lateral distances between the palatal root and the buccal roots of the first molars will produce a great difference in dimensional projection and distortion occurs. The most advantageous position of the anode for

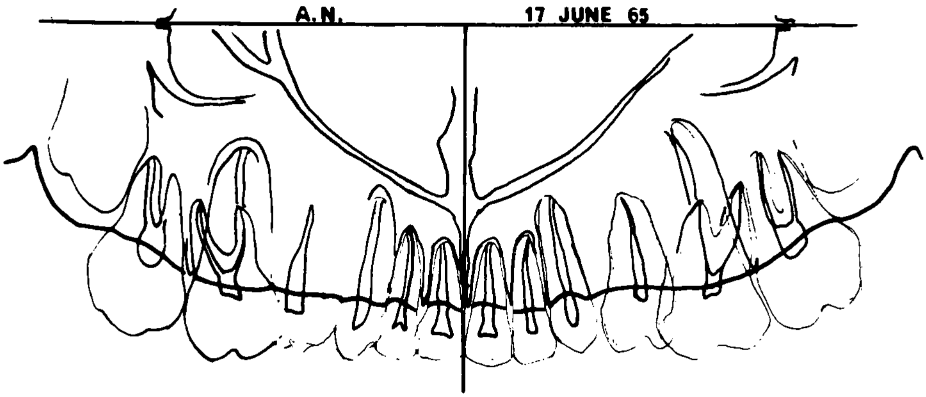


Fig. 3 Sample tracing of Panoramix.

minimal distortion on the anterior area is opposite the second molars. Moving the tube farther forward from this position produces unacceptable magnification distortion in the anteriors. This position (opposite the second molars) unfortunately directs the rays obliquely through the area of the usual extraction space or the first premolar. The resulting picture produces a narrower extraction space because of overlapping images. The profiles of the mesiopalatal aspect of the premolar root and the distobuccal profile of the canine root are seen rather than the proximal outlines. An attempt was made to position the tube farther forward to direct the rays at right angles to the extraction spaces. But this produced unacceptable magnifications in other areas particularly the incisors. It was necessary to return to the original position opposite the second molars and to accept this limitation. The plane of orientation for superpositioning study of tooth movement is drawn bilaterally through the zygomaticofrontal suture. This suture is observable and reproducible and has been accepted as our plane of orientation. From this plane a perpendicular is dropped to the midpalatal suture of the maxilla in the area of the central incisors. Measurements of tooth movement are taken from these two planes of reference. The outlines of the teeth are traced on the standard acetate film, the technique compares with our familiar cephalometric tracing procedures (Fig. 3). The very fine focal spot and the magnification factor produce films of exceptional radiographic definition. We have considered the following areas in evaluating tissue response.

1. *Alveolar bone:* movement of teeth is indicated by increasing thickness of the cribriform plate (lamina dura) on the tension side and the absence of a cribriform plate on the pressure side. Radiolucent areas show in the narrow spaces beyond the cribriform plate and it is suspected that these are areas of undermining resorption. The height of the alveolar crest is readily apparent and traceable. This is one of the key measurements in the study. This line is readily observable and the details of bony architecture are unsurpassed by any other radiographic technique. The alveolar bone is the crux of the future periodontal health of our patients and we should like to determine the permanent effect of orthodontic tooth movement.

2. *Periodontal membrane spaces:*

changes in width are apparent and are indications of pressure and tension areas, and the direction of tooth movement.

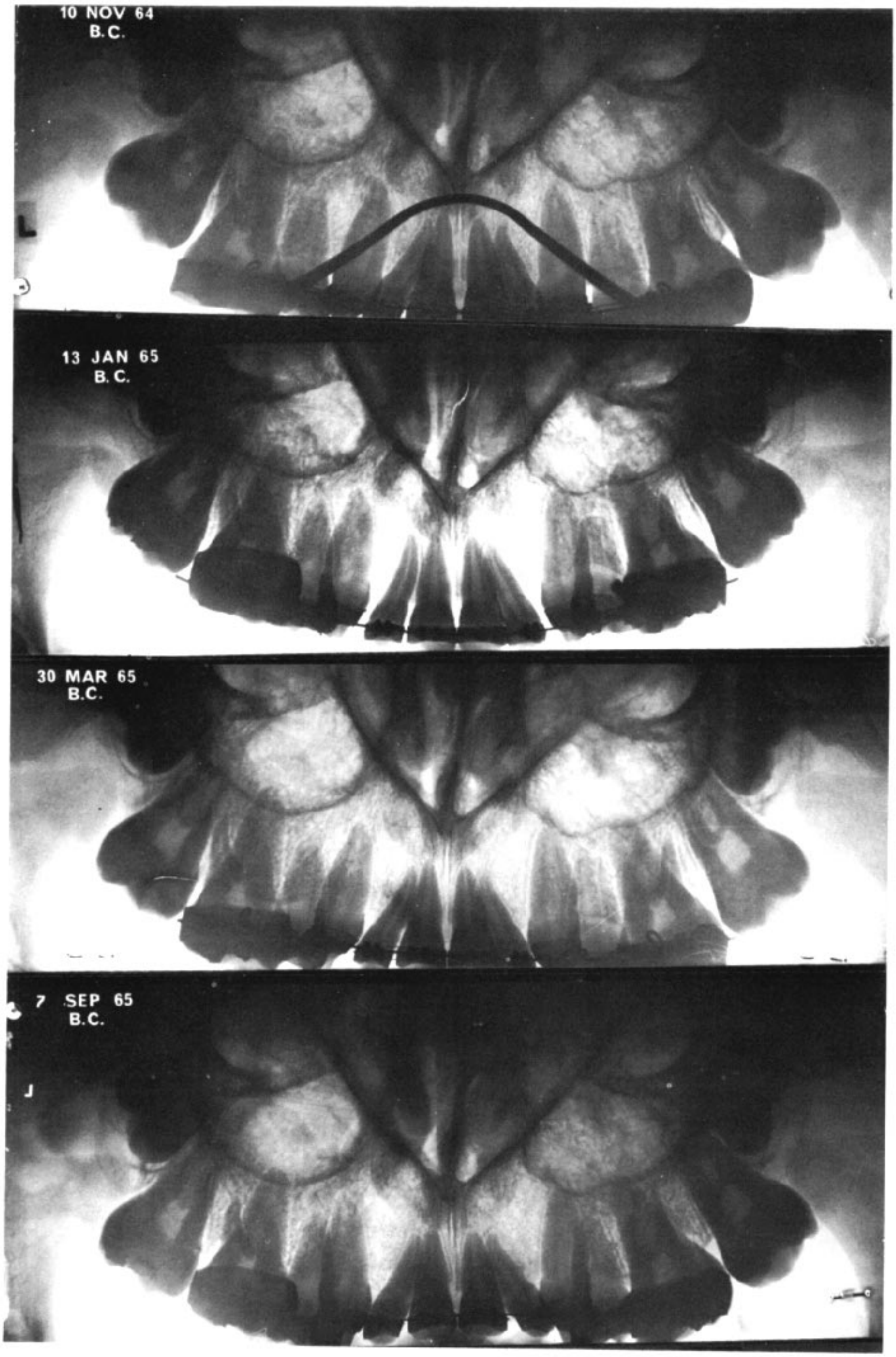
3. *Cementum resorptions:* radiographic changes in the outline show graphically in this technique.

We do not have enough material yet to make any kind of a statistical evaluation of the extent of injury to the periodontal tissues ensuing from orthodontic tooth movement. Nor have we followed our cases for a sufficient length of time to evaluate the extent of healing or a continuing process of damage. We have observed in most of the cases followed a much higher percentage of alveolar bone, cementum resorptions and other potentially injurious changes in the investing tissues than we had formerly suspected. What the ultimate periodontal health of these patients will be remains to be seen. At the present we have sixty cases in the study. Another fifty will be added in a few months. These patients have panoramic films taken every three months. The first film is taken before orthodontic treatment starts. We hope to follow this series through active and retention treatment and yearly thereafter.

The following are several typical cases illustrating the types of reaction of periodontal tissues that we have observed.

Series BC

There are four films in this series taken over a period of approximately 11 months. The first roentgenogram shows the patient with a rectangular .018 by .025 edgewise archwire with a palatal button for lateral stabilization. Open coil springs were tied back to retract the canines. This was backed up by headgear. The coil springs were removed when the canine retraction was completed, at the time the third radiograph was taken. The even increase in thickness of the cribriform plate on the mesial aspect of the canines on film #2 clearly indicates bodily distal movement of these teeth. The periodontal membrane space is also wider on this surface denoting the tension side. Moderate cementum resorption bays, very small in film #1, become quite pronounced in the second and are definitely repairing and filling in on the third film. These are pronounced on the left canine at the distal-apical aspect. Significantly, these cementum resorptions which occur quite rapidly on the proximal surfaces seem to repair and fill in just as rapidly. The distal surfaces of the canines show an absence of cribriform plate and a narrow periodontal membrane space. This would indicate the pressure side. The right second premolar demonstrates a different type of cementum resorption. Damage to the apices of both roots is somewhat diffuse but definite. In the second film the apex is shortening with the typical ragged type of resorption we have observed when the apices are affected. The third film shows a considerable loss of root and a definite blunting-off. The left lateral incisor also shows a definite apical loss and the right central shows the beginning of the same process. The apical resorption of the incisors seems to have been initiated with the application of root torque. We have observed this occurring in other cases undergoing root torque. The left lateral also demonstrates a distal bodily movement with a wide periodontal membrane space and a wide cribriform plate on the mesial root surface and no cribriform plate observable on the distal. Space can be seen opening on the successive films. Note the alveolar crest between the central incisors. The first film shows the alveolar



Series B.C.

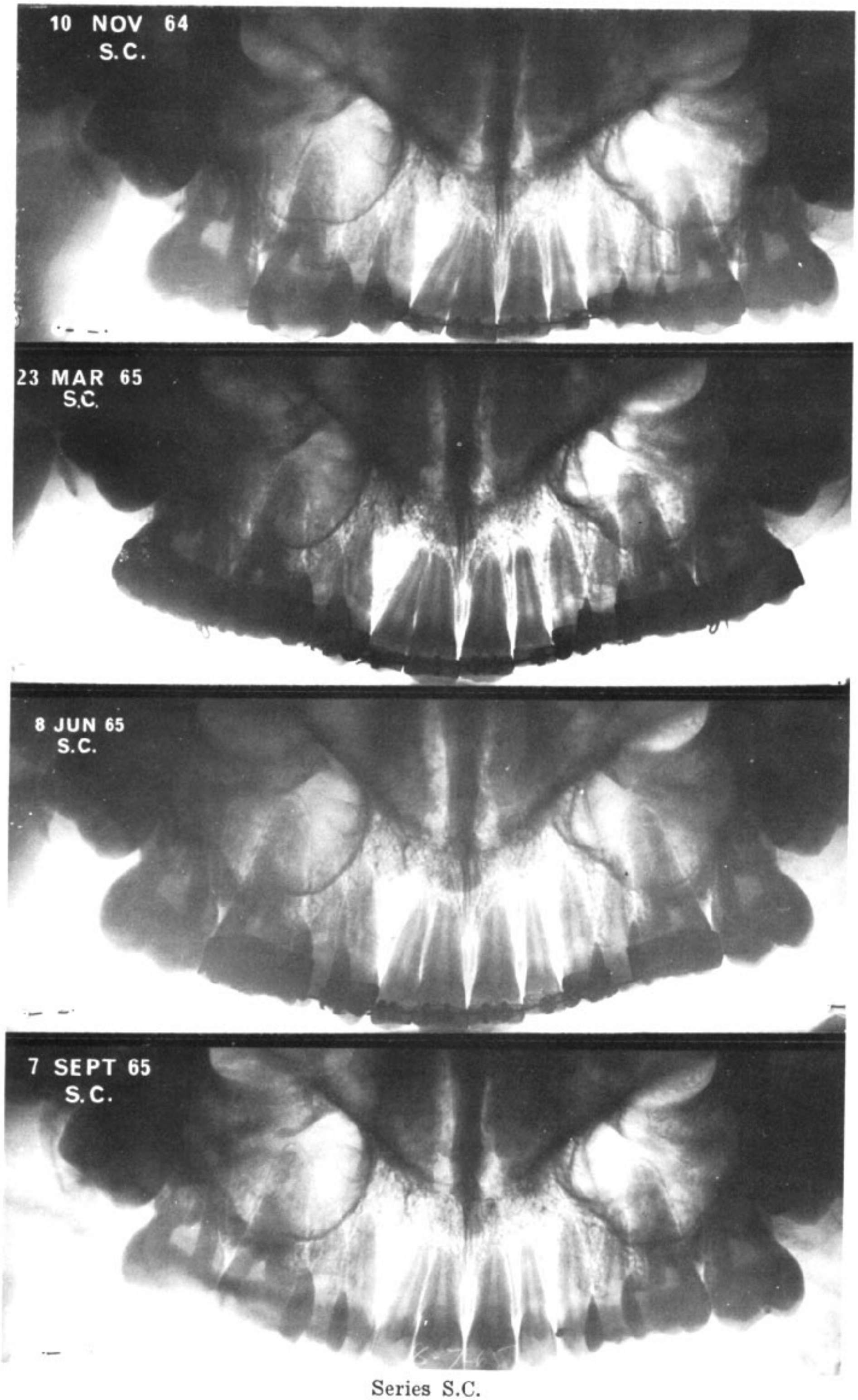
crest close to the cemento-enamel junction. In the second film it is less distinct and shorter. The third film clearly demonstrates an appreciable loss of the alveolar crest occurring over a four month period. Also note the resorption on the mesial of the upper left first molar. In conclusion, this series of films demonstrates definite loss of alveolar bone, large apical resorptions on the right second premolar, and minor ones probably as a result of palatal torque to the incisors. Most disturbing is a considerable loss of alveolar crest to the left central and in the premolar region. On the credit side the proximal cementum resorptions which occur quite readily seem to fill in and repair just as quickly as they form.

Series SC

Six films have been taken over a period of eleven months, four will be shown here. This is a Class II, Division I case in which the first premolars have been extracted. It clearly demonstrates a typical picture of the result of an improperly placed band on the left lateral incisor.

The band has not been driven down far enough on the distal and, as a result, the root is inclined mesially overlapping the central incisor. The study of these panoramic films has increased our awareness of the importance of correct band placement and its effect on root position. This film is a graphic illustration of what happens with an incorrectly placed band. We have observed this occurring quite frequently on lateral incisors. The band was subsequently replaced and the corrective effect can be seen in the next films. The third one shows some space between the lateral and the central incisor roots and some alveolar interseptal bone present. In the first film space closure has been completed between the canine and second premolar. The roots have not yet been paralleled and subsequent films show this situation improving. A wide cribriform plate on the mesial of the canine indicates the tension side and distal movement. As the increased thickness of the cribriform plate becomes uniform, this may be interpreted as translation of bodily movement. The distal surfaces show moderate cementum resorptions mostly occurring in the apical half of the root. The alveolar crest in the extraction space appears normal and is very close to the cemento-enamel junction. However, there has been some loss of height of the alveolar crest in the area of the right lateral incisor and the canine over the course of treatment. The left area also shows some bone loss but less than in the corresponding right area.

In the first film the patient had a rectangular archwire with intermaxillary hooks. Intermaxillary elastics were being worn and palatal root torque had been incorporated into the archwire. A comparison of the films readily exhibits considerable apical root resorption occurring. Particularly, notice the process on the left central incisor. The first film shows a ragged serrated resorption extending mesially at an angle. A considerable part of the apex has been lost in the first film. The second film shows the process more advanced and including more of the distal root area. The final film shows clearly the considerable loss of apical root substance over a period of nine months. Resorptions of the apical area are also beginning on the right central incisor and right lateral incisor. This shows clearly in the last film. The appreciable losses to the root tips have occurred over a relatively short period of time while the anteriors were undergoing retraction and palatal root torque. We can only speculate that, as the apex undergoes the greatest movement



Series S.C.

during torqueing, this is most likely to produce apical resorption. Although we do not have enough evidence to make any kind of a valid appraisal, we have observed similar reactions in other teeth undergoing root torque. As the left lateral is correcting its mesiodistal inclination, the right lateral root has been rapidly tipped distally and the tooth extruded. Note the thickened cribriform plate and the increased periodontal membrane space apically evidenced in the second film. In the third film this space is filling with bone but the apex has begun to resorb on the distal apical aspect. The final film shows reorganization of the periodontal membrane and cribriform plate width but a definite loss of distal apex.

Note also the V shaped radiolucent areas developing on the mesial and distal of the right lateral and also quite pronounced on the central incisor. These are indicators of resorption at the rim of the alveolus and are possibly the precursors of alveolar crest loss. Note the effect of the uprighting of the right lateral in the second and third films. Periodontal membrane space has widened appreciably in the second film by comparison to the first film. This is filling in with bone on the third film. However, the tooth has been rapidly extruded and the root tipped distally in the third film. This has caused the radiolucency in the second and the filling in seen in the third. However, as the root has been forced distally, oblique apical resorption has started in two and is more definite in three. The tooth has been extruded from its alveolus and there has been no concomitant crest growth. Note the difference in crest height between the cemento-enamel junction and the crest in films one and three, particularly on the distal. This tooth has been very quickly elongated and the root rotated distally. There has been a loss of alveolar support at the crest by elongation of the tooth without concomitant crest growth and a further loss of root substance at the apex as a result of cementum resorption. The "veeing" of the crest at the cervix is, perhaps, the beginning of a destructive resorption; it is possible that this will continue. We have had some indication that once the resorption process begins in this area it tends to progress unabated even though the force of the original insult may be lessened. We can only speculate at this point on the future implications of these unfavorable tissue reactions to the periodontal tissues of this dentition. We hope in the future to have more valid information by following these cases over the years.

Conclusions

1. A technique has been developed for standardizing panoral radiographs by stabilizing with a Wehmer cephalostat. Although we cannot consistently reproduce with cephalometric accuracy, we are very close and expect to achieve this. The technique presents some drawbacks but it does provide excellent, qualitative information on a serial basis.
2. We do not have enough material as yet to make any sort of a statistical appraisal as to the effect of orthodontic mechanisms of various types on the periodontium. We have been impressed by the amount of unfavorable change observed in most of the cases studied. It would seem that unfavorable reactions of the investing tissues occur more frequently than we had previously suspected.

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