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A Radiographic Study of Artificially Created Bone Defects in the Mandibles of Human Cadavers

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A RADIOGRAPHIC STUDY
OF ARTIFICIALLY CREATED BONE DEFECTS
IN THE MANDIBLES OF HUMAN CADAVERS

by

PAUL S. VALASEK, D.D.S., B.S.

A Thesis Submitted to the Faculty of the Graduate
School of Loyola University of Chicago in Partial
Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE

MAY

1985

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DEDICATION

I would like to dedicate this paper to my wife Andrea, whose love and devotion helped me throughout this endeavor and to my parents Dr. Charles and Pola Valasek whose love, support, and encouragement made this work possible.

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I would like to thank my thesis director Thomas E. Emmering D.D.S., F.I.C.D., for his constant encouragement, advice, patience and friendship throughout this endeavor.

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I would like to acknowledge the assistance of Rolley C. Bateman D.D.S., for his advice and guidance in interpreting the experimental radiographs.

VITA

The author, Dr. Paul S. Valasek, was born in Chicago, Illinois, March 23, 1956. He attended elementary school at St. Genevieve Catholic School and completed his secondary education at Edwin G. Foreman Public High School, Chicago, graduating with honors in June 1974.

Dr. Valasek attended Loyola University of Chicago, College of Arts and Sciences from 1974 to 1978 graduating with a Bachelor of Science degree in Biology. He entered Loyola University Chicago College of Dental Surgery in 1980 and graduated with a Doctorate of Dental Science in 1984. Dr. Valasek attended the graduate department of Loyola University of Chicago from 1978 until 1985 majoring in Oral Biology and received his Master of Science degree in 1985.

Dr. Paul S. Valasek is the son of Dr. Charles E. Valasek O.D., and Pola A. Valasek, (nee Kostrubala) of Berwyn, Illinois. He is the grand nephew of the late Joseph G. Kostrubala D.D.S, M.D., B.S., F.A.C.S., and the late Marion F. Kostrubala D.D.S., B.S., B.A.

Dr. Valasek married Andrea A. Fash in August 1984 and entered private practice in Chicago, Illinois that same year.

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CHAPTER I

INTRODUCTION

The use of radiographic films in dentistry is a vital adjunct to accurate diagnosis, enabling the clinician to view hard tissue areas of the oral cavity not possible to visualize by the human eye. Bone diseases, if unchecked in an early developmental stage, cause great damage and destruction. Often these defects may be located and identified on the radiograph far before any alterations may be visualized by the naked eye or any clinical signs or symptoms are presented. Early discovery and treatment of dental diseases is advisable and beneficial and may be hastened by radiographic technology.

As important and valuable as the radiograph is to accurate diagnosis, some of its technical limitations and shortcomings may be overlooked by the clinician. These factors must be considered when interpreting radiographs. Recurring variables appear due to:

1. the angulation and projection of the X-ray beam through the tissue layers
2. the physical characteristics of the X-ray beam quality, i.e. HVL etc.
3. an individual's genetic and physical make-up as opposed to other individuals of his own or different race and sex
4. an individual's own physical asymmetry, his calcific patterns, and other anatomical variations

5. film processing methodology
6. clinician's conceptual interpretation of the film

It has been shown that even beyond these recognized variables, the radiograph may fail to portray or image clearly certain bony changes. Bender and Seltzer (1961), described the visual inspection of in vitro specimens where these alterations appeared as drastic defects in bony structures. The problem of defining the parameters involved which cause some of these changes to be apparent radiographically and others not is an area which poses numerous questions.

The purpose of this study was to identify and qualify periapical and supporting bony structure alterations radiographically. By qualitatively demonstrating the degree of bone loss, certain guidelines were developed which may prove helpful to the dentist when utilizing the radiograph for the determination of bony changes.

The relationship between bony defects and their radiographic appearance was established using a custom designed and constructed radiographic paralleling apparatus, a microdensitometer, dental impression materials, photographic records, and visual inspection of sectioned gross specimens.

Radiographic aspects of both endodontic and periodontal treatment were considered in the experimental design with major emphasis placed upon periapical defects.

CHAPTER II

LITERATURE REVIEW

In 1948, Shackman and Harrison studied human bones obtained from autopsies of patients who had expired from malignant diseases which exhibited bony metastases. They visually compared bones with observed metastatic lesions to their contact radiographs and found that the radiographs failed to show bony alterations in more than half of the cases studied. They concluded that radiographs taken of live subjects would be even less discriminating and that one could not identify either the presence or extent of bone destruction from radiographic evidence.

Ardran, in 1951, supported these observations by experimentation with human vertebrae. He drilled holes up to 14 mm. in diameter through the center of the vertebral bodies. These alterations, although known to be present, were not all visible radiographically. Ardran then filled these holes with water and plugged each end with plasticine stoppers. He demonstrated that some of the defects previously detected could not now be radiographically recognized. He concluded that some destruction as great as 1 cm. in diameter may not be detected on a radiograph. He suggested these findings be applied to observation of the entire skeletal frame, reasoning that defects would have to be proportionate in size to the varying dimensions of each bone affected. That is, a 1 cm. defect would easily destroy the cortex in a small bone and be observed on a radiograph. However the same size defect in a larger

bone may not destroy cortex and therefore not be radiographically apparent.

Priebe, Lazansky, and Wuehrman (1954), tested the value of the radiograph in differential diagnosis of periapical lesions. They selected 101 patients who demonstrated radiographically an area of apical rarefaction and found that accurate interpretation of cystic formation and recognition of the abscess-granuloma type of lesion do not warrant sole dependence on the radiograph for description of the parameters of such bone disorders. It was their opinion that radiographs served only as locaters of apical change and were not sufficient to differentiate the nature of the involved pathology.

Also in 1954, Hutchinson stated that in acute apical infections, no radiographic evidence of abnormality may be found although all clinical signs were present. This observation applied to bone infections in general since it took from seven to ten days before sufficient change occurs in bone to be recognized on the radiograph. He also indicated that the value of the radiograph was best evidenced when observing chronic periapical lesions. He listed the principle stages of periapical diseases giving rise to the radiographic appearance of bone and supporting structure abnormalities as follows:

1. thickening of the periodontal membrane
2. chronic rarefying osteitis with no definite bone destruction
3. chronic diffuse rarefying osteitis
4. chronic rarefying osteitis with granulation tissue
5. chronic rarefying osteitis with suppuration
6. chronic rarefying osteitis with cyst formation

Further research by Ennis and Berry in 1959 corroborated this previous work.

Goldman, Millsap, and Brenman (1957), experimented with dried bone specimens of mandibles and maxillae to determine:

1. the origin of registration of the architectural pattern of the buccal and lingual alveolar plates
2. the origin of registration of the lamina dura and the interdental alveolar crest

Sectioning of the bone specimens included removal of the lingual alveolar plates, sectioning through the central fossae and then grinding a section of buccal surface to a remaining thickness of approximately 3 mm. Complete radiographic and photographic records were taken prior to and after alterations.

It was concluded that removal of the buccal and lingual alveolar plates in both mandibles and maxillae had no effect on the radiographic appearance of trabecular patterns surrounding the teeth, nor did the removal of these plates have any effect on the radiographic appearance of lamina dura or the periodontal membrane space.

Goldman, Millsap, and Brenman, also stated that the buccolingual dimension of a radiolucent area could not be determined accurately from a radiograph and that it was not possible to determine if one or both cortical plates were involved due to the masking effect of trabecular bone. Therefore, this masking effect could allow a part of the cortical plate to be missing without being detected on the radiograph.

Updegrave (1958), studied normal radiodontic anatomy and concluded from his data that in normal healthy teeth, a complete and uniform radi-

opaque line outlining the periphery of the root is the exception as opposed to previous descriptions of the lamina dura being an "even thin white line." He further stated that differences in the thickness of the periodontal space is a result of the individual's anatomy and individual stresses placed upon the tooth root in different areas. He concluded that variations in lamina dura continuity and uneven periodontal space widths were normal and not a definite signal of periapical pathosis.

The first major definitive work on artificially created bony defects and their radiographic appearances was reported by Bender and Seltzer in 1961. In a two part study, they experimented with both wet and dry cadaver mandibles creating periapical and periodontal defects with burs, endodontic reamers and files, and diamond stones.

They found that holes drilled in the buccal plate up to one millimeter in depth regardless of bur size were radiographically undetectable. Those lesions greater than one millimeter in depth which were detectable could not be identified as being on the buccal or lingual surface solely through the use of the radiograph.

In further experimentation, Bender and Seltzer demonstrated that defects entirely in cancellous bone could not be detected radiographically when the bone was removed to the cortical plates. When a bur was used to erode the innermost surface of the bone cortex, a clear and distinct radiolucent shadow appeared.

They concluded that:

Bone lesions could be detected on the ordinary intraoral roentgenogram only if there was a) a perforation, b) extensive destruction of the bone cortex on the outer surface or c) erosion of the cortical bone from the inner surface.

Lesions confined within the cancellous bone could not be seen on the roentgenogram.

The apparent cancellous destruction or loss of the trabecular pattern that is visible on the roentgenograms is often due to an erosion of the innermost surface of the bone cortex at the junction area between cancellous and cortical bone.

The term "junctional bone" was first coined by Bender and Seltzer to describe the interface of cortical and trabecular bone.

In part two of their study, Bender and Seltzer extracted a single mandibular tooth and introduced reamers and files up to size no. 4 to a depth of 5 mm. beyond the apex of the socket. Radiographs were taken with and without the instruments in place. No radiolucent changes could be detected from alterations in cancellous bone made by reamers and files up to size no. 4 and by burs up to size no. 2. Bony alterations were recognized radiographically when instruments wide enough to encroach on the cortical plates were used.

They also concluded that the apices of most teeth are lodged in or near the buccal cortex. This close proximity of apex to cortex explains why some periapical lesions are discovered earlier than others and that inflammatory or tumorous lesions cannot be recognized if they are confined within cancellous bone.

In 1961, Barr evaluated the scope and limitations of diagnostic radiography and concluded that:

it is in respect to pulp and periapical conditions that the application and interpretation of roentgenographic findings toward diagnosis is inextricably interwoven with the data available from subjective and physical examinations, pulp sensitivity tests and, at times, laboratory studies.

He concluded that too much dependence on the radiograph was inadvisable. However, at times the radiographic film might be the only key to detecting a periapical problem.

In 1962, Ramadan and Mitchell conducted experimental bony alterations on one human dried skull. After sectioning the mandible for easy access to trabecular bone, a no. 559 fissure bur and straight handpiece were used to create defects manually simulating the appearance of pathoses. It was found that vertical defects less than 3 mm. in depth in the buccal or lingual alveolar crest, leaving the inner and outer plates and their junctional trabeculae intact, failed to appear and be recognized on the radiograph.

Furthermore, removal of lingual or buccal plates failed to alter markedly the radiographic appearance of the bony specimen. The periodontal membrane space and trabecular pattern remained essentially the same after removal of buccal or lingual plates. This was in agreement with Goldman, Millsap, and Brenman.

Ramadan and Mitchell found that defects created by removal of the central trabeculae of the mandible and maxillae, leaving the junctional trabeculae and cortical plate intact, could not be detected radiographically. This was in complete agreement with Bender and Seltzer's previous conclusions. They suggested that diagnosis of most periapical lesions might be enhanced by using an aspiration technique to extract fluid from the lesion through the missing or very thin cortical plate.

Regan and Mitchell (1963), surveyed cadaver specimens for the presence of periapical radiolucencies. Of the 289 periapical areas examined, 18 periapical radiolucencies were found, 12 in maxillae and 6 in mandibles. The lesions were further divided by size and presence or absence of cortical plate perforation. Of the 14 lesions which perforated cortices, all but one were through the buccal plate. This finding

was in agreement with Bender and Seltzer's viewpoint that the buccal plate was most frequently involved in periapical pathoses. The four lesions which did not perforate the cortical plate were similar in shape to those 14 involving perforation but showed less radiolucency on radiographs of the specimens. Perforation of the remaining cortical plates was judged to be imminent for all four and the junctional trabeculae were destroyed. This was also in agreement with Bender and Seltzer as to the extent of bone destruction necessary for radiographic recognition. Regan and Mitchell concluded that the amount of bone destruction could not be determined accurately from the radiograph and that the size of the radiolucency did not necessarily indicate the presence nor absence of cortical bone.

In 1964, Garber undertook a survey of periapical lesions occurring in 1000 patients picked at random from the endodontic clinic of the University of Michigan Dental School. He considered the following four points:

1. interpretation
2. frequency of occurrence with teeth requiring endodontic treatment
3. areas of occurrence
4. resolution following endodontic treatment

From the cases studied, Garber concluded, "Periapical roentgenolucencies are more common in every region of the mandible than in the corresponding region of the maxillae." Furthermore, it was shown that anterior regions were the most frequent sites for periapical lesions followed by molar and premolar regions respectively. He also concluded

that a radiograph could not identify a cyst from a granuloma and that infection could only be identified conclusively by bacteriological methods. These findings were also confirmed by Linenberg, Westfield, Waldron, and DeLaune in work published that same year.

Wengraf, (1964), confirmed the work of Bender and Seltzer. He created artificial defects in the medulla of mandibles and maxillae of dried skulls and demonstrated their invisibility on the radiograph. Wengraf concluded that the areas of rarefaction evident on the radiograph were not the true shape and size of the lesion but only of that damage done to the cortical plate. Other conclusions drawn were that dried bones provided greater radiographic contrast than bones in vivo and if a defect could not be seen in a dried specimen radiograph, it would not be detected in a live patient with wet bone and overlying soft tissue. He also concluded that some periapical lesions may be radiographically detected earlier on some types of teeth than others due to the close proximity of their root apices to cortical plates. This caused earlier cortical plate destruction which produced a radiolucent area on the radiograph.

Pauls and Trott (1966), experimented with sections of dried human mandibles. Their results were in agreement with those obtained in previous studies by Bender and Seltzer and by Wengraf. They drilled various size holes into and through the buccal plate of the mandible. It was demonstrated that a lesion or defect will not appear radiographically unless it has perforated the cortical plate or has eroded the inner surface of the junctional bone. Pauls and Trott also concluded that lesions confined solely within cancellous bone could not be

detected radiographically and that loss of trabecular patterns in radiolucent areas were due to the erosion at the interface of cortical plate and cancellous bone. It was also demonstrated that by varying the exposure times, all defects with a depth of 0.5 mm. in the outer surface of the cortex and some defects with a depth as great as 1 mm. could not be seen radiographically.

Rees, Biggs, and Collings (1971), studied 41 human skulls, 11 intact cadaver mandibles and 9 intact cadaver maxillae for naturally occurring bone defects. Among the defects were:

1. proximal intraosseous defects
2. interproximal craters
3. interproximal hemisepta
4. inconsistent margins
5. alveolar fenestrae
6. alveolar dehiscences
7. furcal defects on multirooted teeth
8. facial or lingual one-walled defects

Of the 150 furcation defects present, 129 could be detected radiographically. They concluded that furcation defects on facial and lingual surfaces of multirooted teeth could be identified with a high degree of accuracy from their radiographic appearances.

In October of 1971, Schwartz and Foster duplicated portions of Bender and Seltzer's experiment. All periapical experimentation was performed on the alveolar process of two mandibular molars of a dried skull specimen using exposure times of 3.5 seconds at 70 KVP and 10 Ma. Access into the bone was through the socket of the extracted second

molar and through the buccolingual sectioning of the body of the mandible in the area of the third molar. A no. 8 round bur was used to simulate a periapical defect around the socket apex and a no. 1 Molt curette was used to remove the central portion of cancellous bone in the sectioned portion of mandible.

No radiographic appearance of a defect was observed of the extracted second molar and the only change in film appearance for the sectioned mandible defect was a general increase in radiodensity in the area of defect. In both of these cases, only cancellous bone was removed, supporting Bender and Seltzer's findings.

Phillips and Shawkat (1973), used panoramic and conventional intraoral radiographs to study artificially created osseous defects. Ten dry human mandibles were mounted on acrylic bases for exact positioning and bite blocks were used for the film placement and tube alignment. All mandibles were sectioned distal to the first molar to obtain best results with use of the Panorex. Utilizing dental burs, defects were created which were totally in cancellous bone. The greatest dimension of any defect did not exceed 5 mm. and none encroached on cortical bone. The unlabeled films were evaluated by 20 dentists and 20 senior dental students. Phillips and Shawkat concluded from the data gathered, that defects produced in dry specimens appeared more distinctly on panoramic radiographs than on intraoral radiographs, regardless of cortical plate involvement. They further concluded that the defects produced observable images on both panoramic and intraoral films but were more demonstrable on the panoramic radiographs.

In 1974, Shoha, Dowson, and Richards, produced artificial bone lesions and studied their radiographic appearances. One dried human adult mandible was embedded in a large plastic platform to align it with an X-ray source. Radiographs were produced prior to any bony alterations to establish a standard. Each radiographic film was exposed for 2 seconds at 55 KVP and 10 Ma. and all film processing was kept identical.

The teeth under study were then extracted and the mandible was sectioned longitudinally. After removal of the left lingual plate and right buccal plate, defects were created around the apices of the sockets and gradually enlarged until radiographically observable. Photographs were taken to show any involvement between junctional bone and the artificially created defects. The apical areas of the two mandibular second molars and all four mandibular premolars were experimentally altered. Both molar defects involved cortical plates before a roentgenolucency could be visualized. In the premolar region, all the lesions were radiographically evident before any involvement of junctional bone or cortical plate. This was not in agreement with Bender and Seltzer and other previous studies.

Shoha, et. al., suggested that the cortical plates were thinner in the premolar region than those in the molar region and that the X-ray beam was not attenuated as much in the premolar area, thus yielding greater radiographic contrasts. They also stated that the lesions were larger than their radiographic appearance though only a slight difference in size was shown in the premolar area.

Duinkerke, Van de Poel, De Boo, and Doesburg (1975), studied the accuracy of interpretation of periapical radiolucencies. Ten dentists

were given the task of tracing the area and contour of definite periapical lesions from enlarged slides of radiographs. The tracings were measured with respect to:

1. the greatest distance between the root and the border of the radiolucency
2. the greatest diameter of the radiolucency
3. the total area of the radiolucency

Results showed that the average relative error of interpretation was 21% for the areas of the readily defined radiolucencies, and 37% for the areas of diffuse radiolucencies. When the dentists' drawings were compared, the relative error of interpretation represented by measurement of the area varied from 14 to 32% for the readily defined radiolucencies and from 23 to 52% for the diffuse radiolucencies.

Further research on radiographic interpretation was done by Duinkerke, Van de Poel, Doesburg, and Lemmens in 1977. A human dried mandible was mounted on a platform and sectioned buccolingually to gain access to the apical region. Radiographs were taken before and after each experimental step. The interpretation of the films was the concern here and not the matter of junctional bone or cortical plate involvement. All films were evaluated with a densitometer to establish the parameters of the defects. The same radiographs were then interpreted by ten dentists who were asked to trace the extent of the radiolucent areas. Densitometric measurements of the radiographs were presented in graphs and isodensitometric images. Areas where bone was removed could be distinguished with reproducible accuracy by densitometric analysis whereas the interpretation of the same radiographs by the ten dentists differed greatly.

In 1977, LeQuire, Cunningham, and Pelleu continued research on experimentally produced lesions and their radiographic interpretations. They studied artificially created apical lesions in ten dry human mandibles, four of which were evaluated dry and the other six were evaluated utilizing a soft tissue phantom to simulate wet specimens. The dry specimens viewed without a soft tissue phantom were designated Group 1 and had 45 artificially created periapical lesions. The specimens viewed with a soft tissue phantom were designated Group 2 and had 23 periapical areas artificially altered. All mandibles were sectioned mesiodistally to gain direct access into the apical region. Lesions were created using a no. 4 dental bur in the apical regions of 24 premolars and 29 molars. These lesions were of varying sizes and shapes and did not encroach upon nor enter the junctional bone or cortical plate. After evaluation of the radiographs by the senior author and five other dentists, results showed that 78% of the lesions in dry specimens and 95% of the lesions in the specimens with the phantom were detected. This was in sharp contrast to Bender and Seltzer's previous work. The difference in the percentage of visibility between the first and second groups was not statistically significant.

In October 1977, Duinkerke, Van de Poel, Van der Linden, Doesburg, and Lemmens, established a technique for standardizing clinical periapical radiographs. The basis of this study was the misinterpretation of sequential radiographs which showed apparent healing of periapical pathoses even when repair was not actually present. They emphasized that apparent changes and radiographically evident healing of bony structures may in fact be due to the projection of the X-ray beam at different angles through the tissue and onto the film.

A paralleling instrument with an orientation bite block was designed to provide standardized projections on periapical radiographs using the extension cone paralleling technique. The measurements of selected distances were made on three serial radiographs taken on the teeth of each of five endodontically treated patients. The three serial radiographs were obtained at one week intervals and the error in estimating predetermined distances proved to be very small (0.05 mm.). This method proved to be clinically applicable for patients.

In 1977, Wuehrman and Manson-Hing stated the limitations of the radiographs for periapical diagnosis and described the early signs of developing periapical radiolucencies. They stated that periapical changes may be observed radiographically as:

1. no change in osseous configuration when acute clinical symptoms are present
2. periodontal space thickening
3. interruption in the continuity of the lamina dura

These signs seem in agreement with those previously described by Updegrave. It was also stated that root apices may be curved, turning toward the buccal or lingual so that the apices are not clearly visible on the radiograph. Early signs of periapical bone damage may not be seen until the size of the lesions extend beyond these anatomic variations and are outlined by the X-ray beam.

Following discussion of the early signs of periapical radiolucencies, they further stated that the radiograph is an adjunct to oral diagnosis and that clinical findings must be considered along with the radiograph before a definite diagnosis can be made.

Duinkerke, Van de Poel, Van der Linden, Doesburg, and Lemmens (1978), investigated the density changes found on standardized radiographs of identical subject matter taken at different time intervals. These density changes were due to variations in:

1. kilovolt peaks
2. soft tissue thickness
3. exposure times
4. developing times

By affixing a penetrometer to each film and reading the exposed films through a densitometer, density values were converted to millimeters of aluminum equivalents. This method was used to equilibrate the variations in film densities due to the stated variables, and as a result showed only density changes due to alterations in the bony structures. They concluded that this method had clinical applications.

Volchansky and Cleaton-Jones (1978), studied 43 dried Bantu mandibles for frequencies of occurrence of apical defects, bifurcation involvements, dehiscences, and fenestrations. These specimens were visually and radiographically inspected and all identifiable defects recorded. Visual examinations revealed buccal periapical defects adjacent to 1.1% of the teeth. Upon radiographic inspection of all specimens, defects were identified in 0.8% of the teeth. The greater number of visual identifiable defects may be attributed to the fact that some did not progress far enough to be seen radiographically. However, there was no significant statistical discrepancy between visual and radiographic findings.

CHAPTER III

MATERIALS AND METHODS

Ten human mandibles were obtained from the Gross Anatomy laboratory of Loyola University Medical Center. These were predominantly from elderly male and female cadavers. All but two of the specimens had been previously sectioned in the midline and two were without condyles. Dentitions varied from a full complement to one or two remaining teeth.

All soft tissue was carefully dissected and removed. After cleaning the mandibles with a soft brush and water, each individual section of the mandibles was assigned a number and appropriately labeled. Color photographic records were made of each specimen from both buccal and lingual views, (Appendix A).

Due to the nature of dissected cadaver mandibles, paralleling instruments commonly used in clinical radiographic procedures could not be utilized. Therefore, a custom designed paralleling apparatus was constructed meeting the following technical criteria:

1. Accuracy and Precision: The device must be constructed in design to produce an accurate and precise radiograph of the specimen.
2. Reliability and Reproducibility: The device must be capable of reliably reproducing radiographs with respect to angle of the X-ray beam, positioning of the film packet, (i.e. serial radiography).

3. Adaptability: The apparatus must be designed and constructed so that paralleling technique factors remain constant while radiographing different specimens in their mounts.
4. Ease of Handling: The entire device should be readily portable and adaptable to any commonly used clinical X-ray generating system.

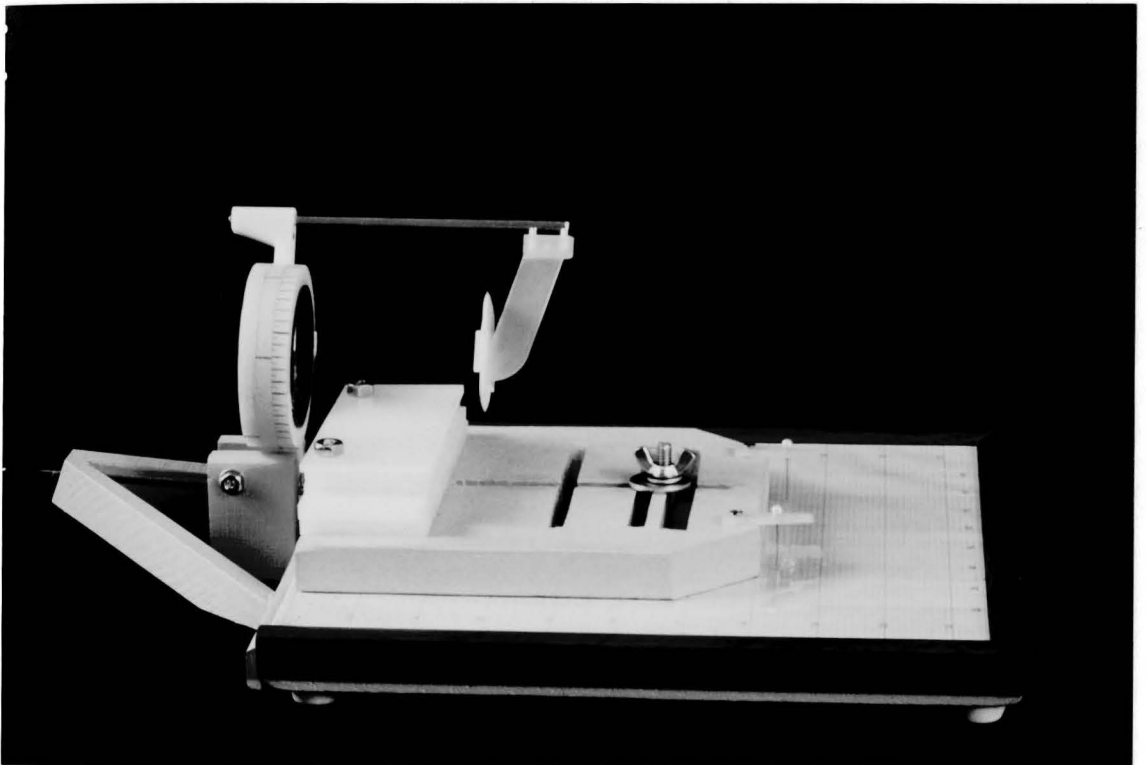
The specimen mount must possess two qualities: it must be fixed to the specimen and it must be able to be repositioned consistently upon the apparatus.

Following these parameters, the paralleling apparatus was designed and constructed in three parts. (Fig. 1) 1. an alignment base with positioning chart, 2. a movable mounting block for attachment of the mounted specimens, and 3. beam paralleling rings for alignment of the X-ray collimator, specimen, and film packet.

The alignment base (Fig. 2), consisted of $3/4$ inch particle board measuring 11 x 11 inches and covered with ruled graph paper 10 x 10 to the inch, which was aligned and securely affixed to the board. Abscissas and ordinates were appropriately marked and the entire surface was covered with a clear protective acrylic sheet. Through the center of the alignment base, a $1/4$ inch hole was drilled and a $1\ 3/4$ x $1/4$ inch bolt was inserted and secured into position. This bolt provided a fixed post upon which the mounting block could be placed and allowed to pivot.

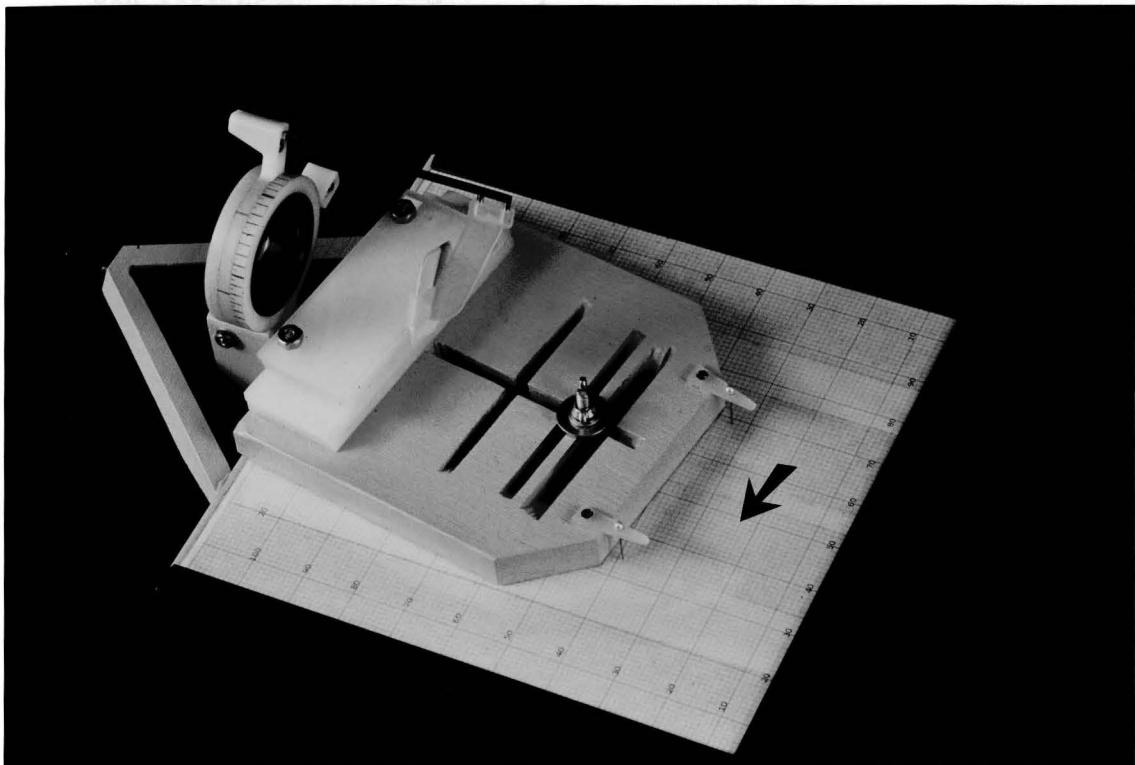
The mounting block (Fig. 3), consisted of a block of wood $6\ 3/4$ x 7 inches. This block was cut with three slots, two parallel and one perpendicular bisector which allowed pivoting and positioning of the

Figure 1: Paralleling Apparatus



positioning ball. The alignment base was made from a piece of black acrylic. The two ends were drilled and threaded. The balls were inserted in Figure 2: Alignment Base. The two adjustments on the front of the base. Two polished steel balls were used for the spring. The initial positioning and replication of the film is on graph in the alignment base (Fig. 5).

Six fiberglass rectangular spacers of varying thicknesses were cut



positioned for the positioning ball of the remaining block.
 The polished ring carrier was aligned with a corresponding hole
 in the block. The plastic film was fixed to the block using a
 small amount of adhesive. The spring steel ball was positioned
 against the film. The first plastic film was placed
 against the film.
 The thickness of the film was measured.
 The thickness of the film was measured.

mounting block upon the alignment base. On the front of the mounting block, two 1/4 inch holes were drilled and two 2 x 1/4 inch positioning bolts were inserted and secured into place to hold and align the specimen mounts on the mounting block. Two pointers were fixed to the rear of the mounting block for initial positioning and repositioning of the block to the graph on the alignment base, (Fig 4).

Six fiberglass rectangular spacers of varying thicknesses were cut 2 x 4.5 and 2 x 5.5 inches using a fine tooth blade and radial arm saw, and two identical holes were drilled through each spacer for positioning over the specimen bolts. Utilizing various spacer thicknesses, each mounted specimen could be positioned in a correct relationship to the X-ray beam.

Each mandible was mounted on its own fiberglass base using Coe Custom Tray Plastic,¹ (Fig. 5). The mandibles were positioned in a perpendicular plane to the fiberglass mounts. Custom tray plastic was packed tightly along the inferior borders of the mandibles, held firmly against the mounting rectangles, and allowed to cure, firmly attaching the mandibles to the fiberglass bases. Each mounted specimen, (on its fiberglass base), could be placed and secured with wing nuts in an exact position over the positioning bolts of the mounting block.

The parallel ring complex was adapted from a Rinn Paralleling Kit.² (Fig 6) Two plastic rings were fitted over a thin spring steel band allowing rotation around the spring steel band but preventing lateral movement or separation. The first plastic ring was made

¹ Coe Laboratories, Inc. Chicago Il. 60658

² Rinn Corporation, Elgin Illinois

Figure 3: Mounting Block

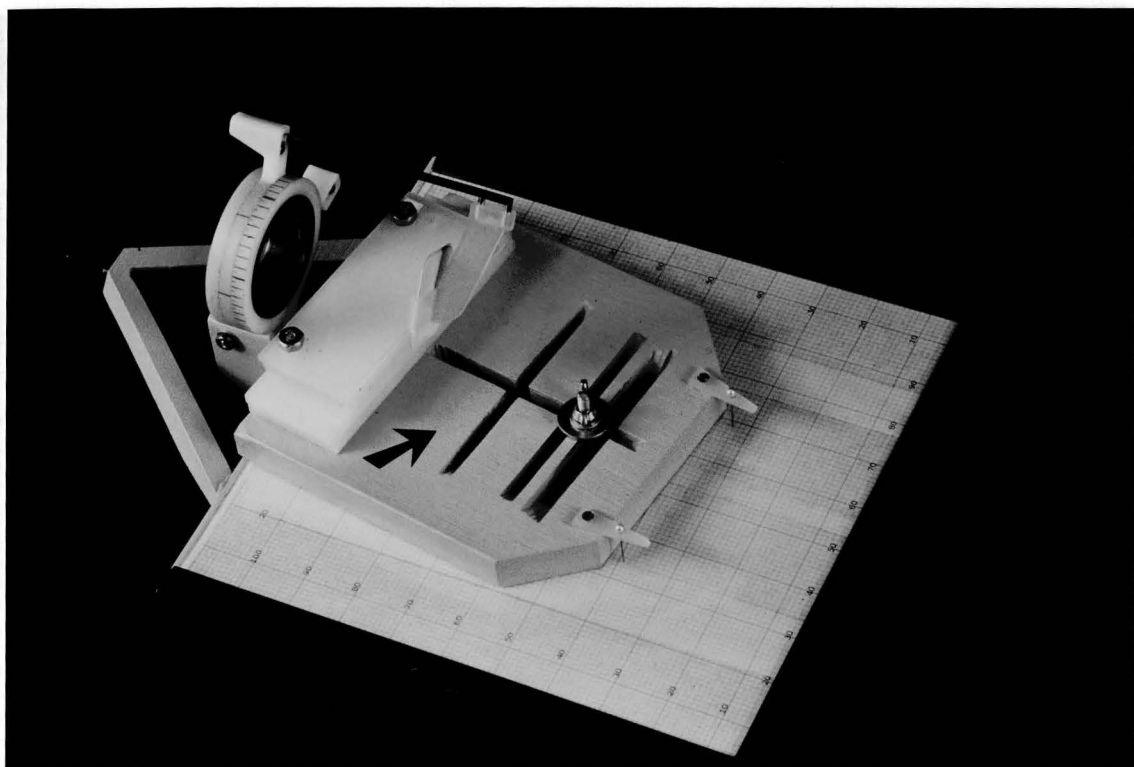


Figure 4: Pointer on Mounting Block

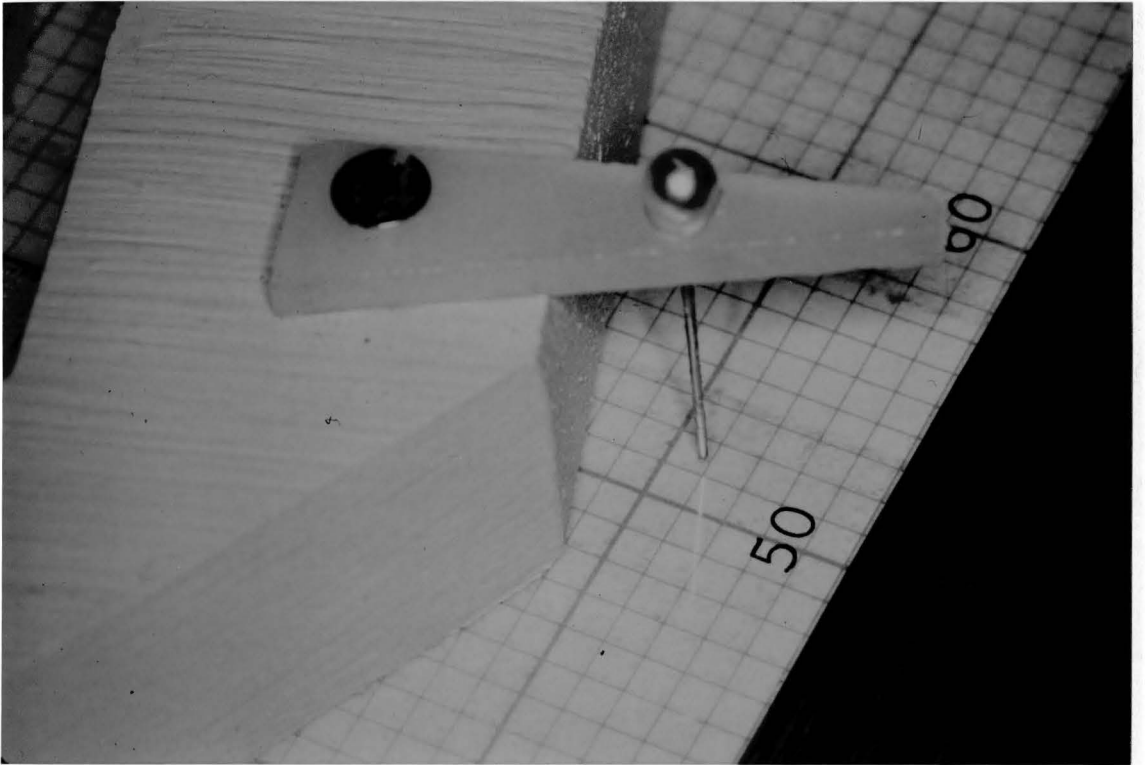
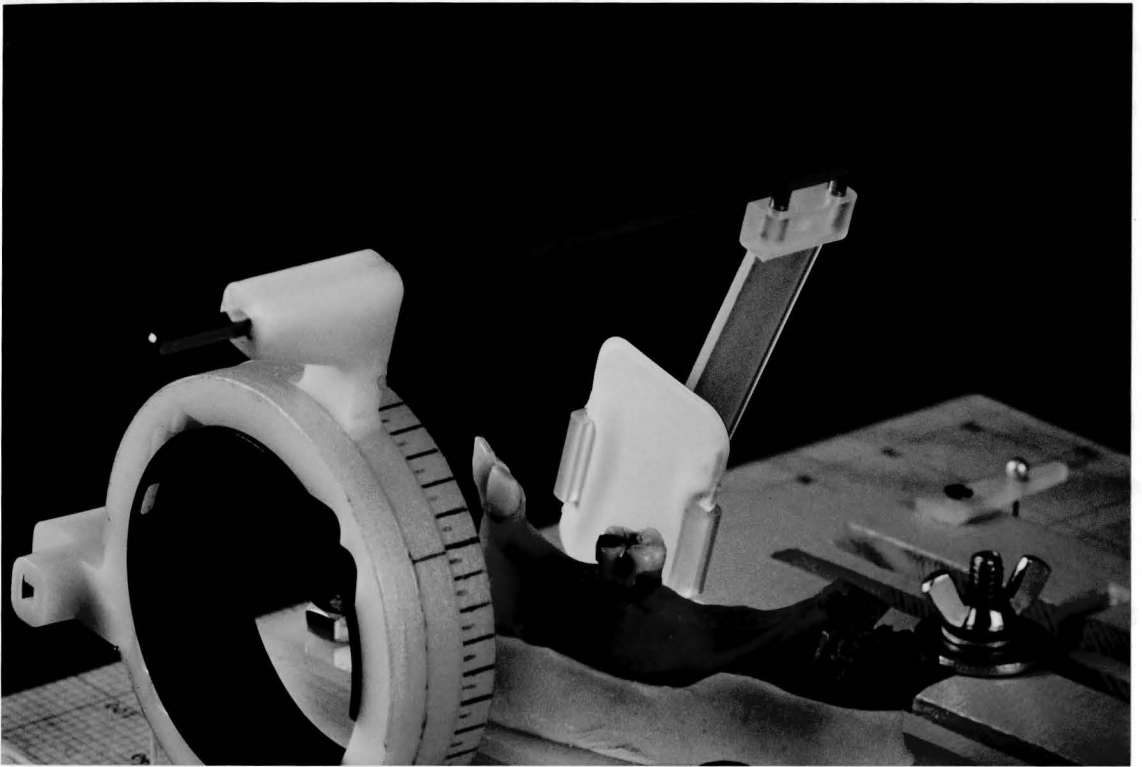


Figure 5: Mandibles in Tray Plastic



stationary by attaching it to the alignment base using a rod from the kit which was secured to the bottom of the base with a screw and washer. Angle and block braces were also attached to the ring complex and alignment base to provide strength and maintain stability when handling the apparatus. The second plastic ring was fitted over the spring steel band, butted flush against the stationary ring, and fitted with a rod and film holder. The stationary ring was scribed with calibration bars along its outer circumference. The movable ring was marked with red and green indicator lines, one on either side of the film holder rod. These markings allowed for accurate repositioning of the rotating ring to the stationary ring when producing serial radiographs of each specimen.

The film holding assembly, (metal rod and film holder), (Fig 7), was inserted into the movable ring and adjusted for each specimen to a measured distance from the parallel ring complex. The movable ring and film holder allowed proper alignment of film and specimen for use of the paralleling radiographic technique.

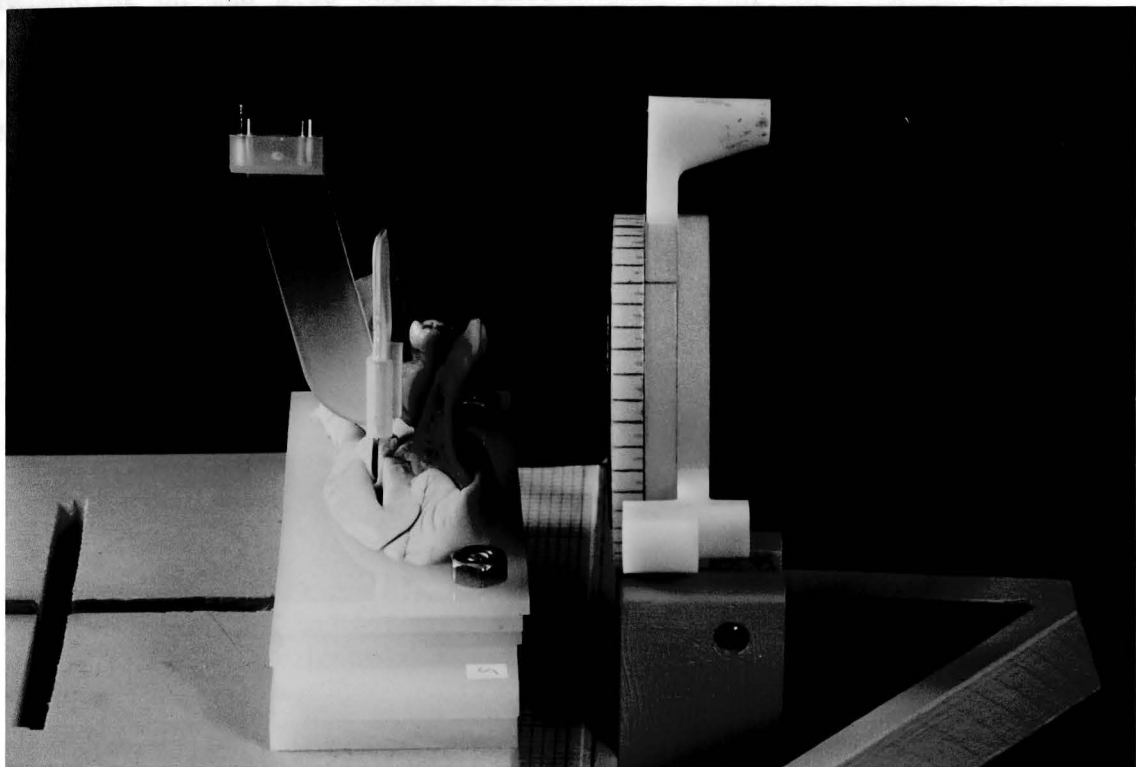
Each specimen was placed as close as possible to the movable ring and positioned so that the long axis of the teeth, the plane of the film, and the ring complex were parallel. The collimator of the X-ray machine was placed flush against the outer surface of the stationary ring, aligning the central ray of the X-ray beam so it would be perpendicular to both the long axis of the specimen and the plane of the film. Duplicate radiographs were taken of the existing mandibular dentitions prior to any experimental alterations and labeled "OR" (Original). The X-ray generator used was an S.S.White Flexomatic,³

³ S.S.White Corporation, X-ray Division, Great Neck, New York 11021

Figure 6: Parallel Ring Complex



Figure 7: Film Holding Assembly



90KVP long beam with appropriate filtration and collimation for clinical use. All film used in the study was Eastman Kodak Ultra Speed Periapical, Size 2, DF-57 and DF-58.⁴ All film packets were selected from the same manufacturer's batch to negate the remote possibility of variations in film emulsion. All radiographic exposures were made at 90 KVP and 15 Ma and exposure times varied from 3/10 to 5/10 of a second depending on the area being studied. These exposure times represent those commonly used in clinical practice, (Table 1). All films were processed in a Philips 810⁵ automatic processing unit, (Fig. 8).

Specimens were selected to represent each mandibular tooth type and included a total of 15 teeth. At this point, extraction of the following mandibular teeth was performed using dental forceps (Table 2). Some dessication was a problem due to the nature of the available specimens. This was lessened by prior immersion of the mandibles in a solution of 10% glycerin in water.

After extraction, the teeth were repositioned in their sockets and a second set of radiographs was produced to establish a standard, labeled "S". This set of radiographs served a dual purpose, 1. to determine the radiographic appearance of any bony alterations due to extraction, and 2. to serve as a standard for comparison of all experimental films through both visual and microdensitometric analysis.

Physical records of the preoperative sockets were obtained utilizing Impregum⁶ impression material selected for its accuracy and

⁴ Eastman Kodak, Rochester, New York 14650

⁵ Philips Dental Systems, Stamford CT 06902

⁶ Premier Dental Products Co., Norristown, PA 19401

Figure 8: Philips 810 Automatic Processor



TABLE 1
X-RAY EXPOSURE TIMES

All at 90KVP and 15Ma

SPECIMEN #	EXPOSURE TIME (Sec.)	MAS (Milliamp Sec.)
6	4/10	6.0
9A 1st Molar	5/10	7.5
9B 2nd Molar	5/10	7.5
13	4/10	6.0
14	3/10	4.5
16	4/10	6.0
17A	3/10	4.5
17B	3/10	4.5
18A	4/10	6.0
18B	4/10	6.0
23	3/10	4.5
24A	4/10	6.0
24B	5/10	7.5
26A	4/10	6.0
26B	4/10	6.0

TABLE 2
MANDIBULAR TEETH USED IN THE EXPERIMENT

SPECIMEN #	TOOTH TYPE	TOOTH #
6	2nd Premolar	20
9A	1st Molar	30
9B	2nd Molar	31
13	Canine	27
14	Canine	22
16	2nd Premolar	20
17A	Lateral Incisor	23
17B	1st Premolar	21
18A	Central Incisor	25
18B	Central Incisor	24
23	Canine	22
24A	Canine	22
24B	2nd Premolar	20
26A	2nd Premolar	20

stability, (Ciesco). By producing impressions of the sockets preoperatively and after each series of artificially created defects, physical records were maintained. These impressions provided a visual record of the progression of created defects and sockets which otherwise could not have been maintained without sectioning the mandibles, a process which would at this time disrupt the study. Each impression was carefully mounted on a pin, labeled "S" for standard, photographed, and stored in an individual container to protect against damage.

The design of this study was such that the defects were created through the socket and into the bone without sectioning the mandible and did not create the defect in the exposed surface of the sectioned mandible as was done in most previous studies. Each lesion was created by removing minute amounts of bone from the apex of the socket using a #6 round bur in a slow speed handpiece. Any dust or small bone particles resulting from the drilling were carefully purged from the socket using an air syringe and each tooth was carefully repositioned into its socket afterwards.

A complete set of radiographs was retaken of each experimentally altered specimen with the specimens accurately repositioned on the paralleling device and using previously established graph coordinates, film positioning measurements and X-ray technique factors. All film was from the same emulsion batch number and processed at the same time using the Philips 810 processing unit (i.e. identical procedures used for "OR" and "S" films). These radiographs were labeled Series #1 and placed into appropriate holders with their "OR" and "S" counterparts.

Impressions were taken as previously described and labeled #1. These were mounted and stored in the appropriate containers with their "S" counterparts.

The second series of defects were created in the same manner as the first series but removed a greater amount of bone from around the apex of the socket. It was at this juncture that, due to the close proximity of the apices of the second premolars to the mandibular canal in specimens #24 and #26, the bur broke entirely through cancellous bone and into the mandibular canal. Radiographs were produced of these specimens. However, no further accurate impressions of the sockets of these two specimens could be obtained. A second set of radiographs was taken and all established processing procedures were followed. These radiographs were appropriately mounted with their counterparts and labeled Series #2, (Appendix B).

The second postoperative set of impressions was taken of all specimens with the exceptions of premolars in mandibles #24 and #26 where the artificial defects had broken into the mandibular canals precluding accurate impression procedures. These Series #2 impressions were mounted, labeled #2, and placed into their corresponding containers. At this point, color photographic records were made, front and side views, of each set of impressions, pre- and postoperative, (Appendix C).

Microdensitometric analyses were made of all the radiographs to define subtle changes in densities appearing in the films as accurately as possible. The microdensitometer used in this study was a Joyce-Loebl double beam recording microdensitometer model MK IIICS, (Fig. 9). Grain

size of dental ultra-speed film required that minimum magnification factors be used to lessen the possibility of error in reading the changes in density values of the films. This sophisticated microdensitometer was limited to a minimum magnification of 20X and therefore no recognizable landmarks could be located with any consistency on the films. Consequently, each set of four radiographs was marked with black ink dots to create accurate reference points for alignment of the instrument. This was accomplished using a fine point felt tip pen and magnifying hand lens, (Fig. 10).

The microdensitometer had the capability of scanning in a single line, any area as exact as 1 micron wide by 1 mm. long. It was practical for this study to use a scanning area .5 mm. X 1 mm. which produced a suitable working graph of density variations. Each set of radiographs representing one specimen and its created defects, (i.e. #13 "OR, S, #1, #2"), was densitometrically analysed as an individual group. All comparison of density changes were made within each group of radiographs representing a single specimen. Each film within the group was aligned using the two black reference dots. The area scanned was a line traversing from a point originating outside of one reference dot and stopping at a point outside the second dot. By this method, both dots would definitely appear on the graphs as the peaks of highest amplitude and serve as alignment markers for superimposition of each experimentally altered specimen's graph upon its standard. The graph table and marking pen were directly driven by the scanning table giving accurate and precise graphs. After each set of radiographs was scanned, which produced individual graphs for each Original "OR", Standard "S",

Figure 9: Joyce-Loebl Microdensitometer Model MK IIICS

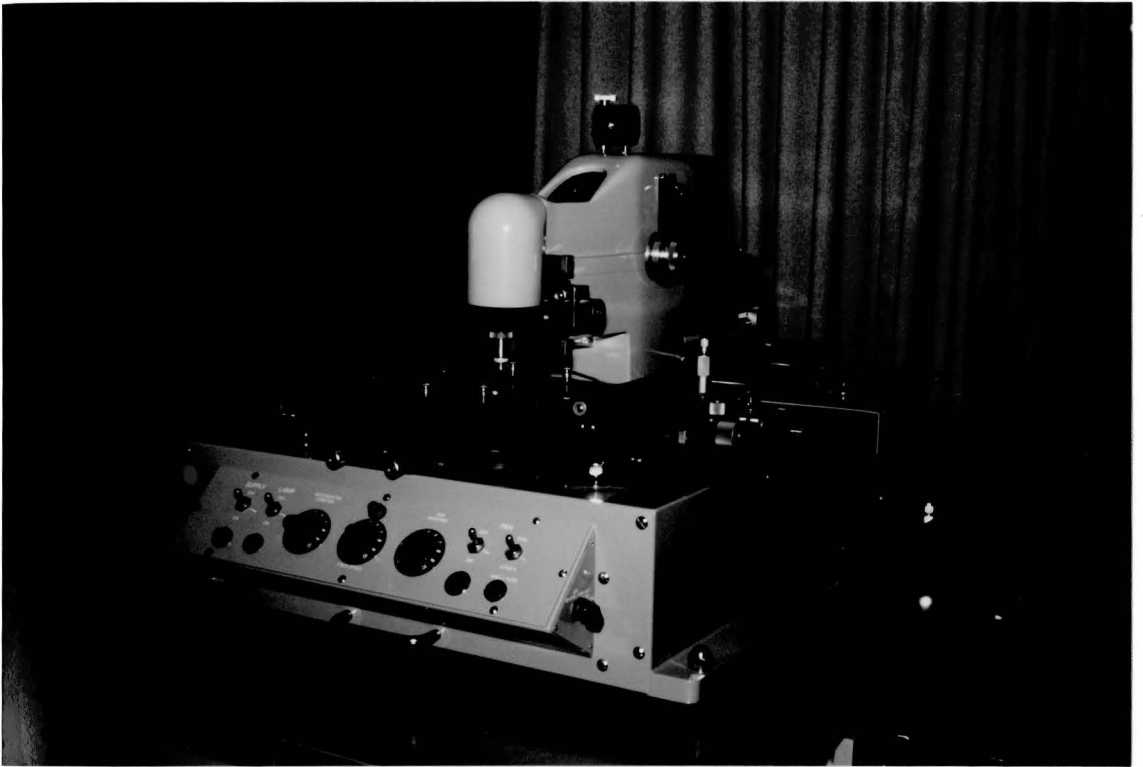
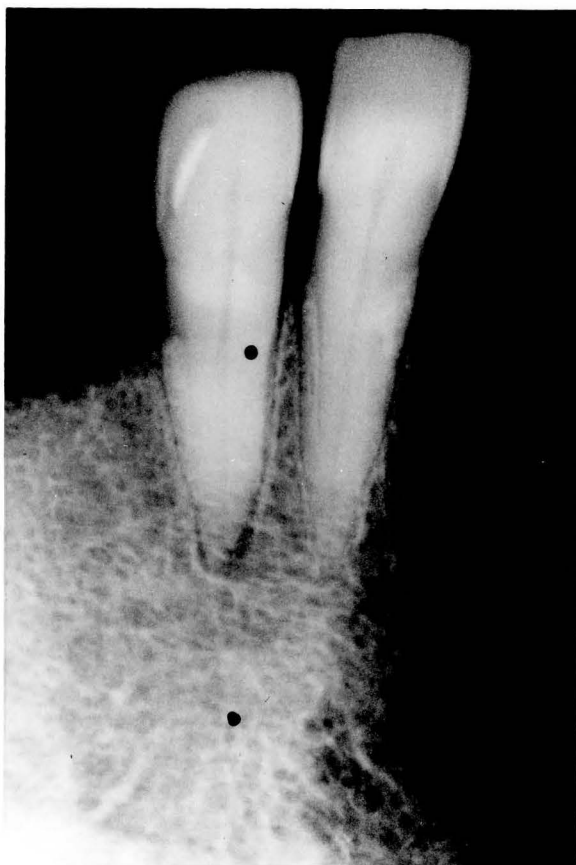


Figure 10: Radiograph with Black Reference Dots



defects Series #1 and #2, a calibration curve was made from which absolute optical density units were obtained.

After all microdensitometric measurements and other records were completed, each mandible was sectioned buccal-lingually through the socket's apex (tooth removed), using a high speed circular saw with a diamond in brass matrix blade held with a precision jig. The cutting blade thickness was 1/10,000 of an inch allowing each sectioned portion to be repositioned with relative accuracy and each tooth could be replaced for further study and photography. Complete color photographic records of the sectioned surfaces were made using an Olympus OM-2 camera and Olympus Stereo microscope model X-Tr, (Appendix E). Using a dissection microscope, each defect was classified as either being totally in cancellous bone or involving both cancellous and cortical bone.

The radiographic sets were viewed using a double blind procedure under standard clinical conditions of a light source and magnifying hand lens. Each film was evaluated for a defect individually, without knowledge of its true identification, i.e. "OR, S, #1, or #2," or the number of the specimen. These results were tabulated by the author and four clinicians, (Table 3).

TABLE 3
RADIOGRAPHIC EVALUATION

SPECIMEN #	DIAGNOSIS OF THE DEFECT	SPECIMEN #	DIAGNOSIS OF THE DEFECT
6 OR	0	18B OR	0
S	0	S	0
1	*	1	+
2	+	2	+
9A OR	0	23 OR	0
S	0	S	0
1	*	1	*
2	+	2	+
9B OR	*	24A OR	*
S	0	S	*
1	+	1	*
2	+	2	+
13 OR	0	24B OR	0
S	*	S	0
1	*	1	*
2	+	2	+
14 OR	*	26A OR	0
S	*	S	0
1	+	1	0
2	+	2	*
16 OR	*	26B OR	0
S	+	S	*
1	+	1	*
2	+	2	+
17A OR	0		
S	0	Key 0 = No visible lesion	
1	*	* = Possible lesion	
2	+	+ = Definite lesion	
17B OR	0		
S	0	OR = Original (pre-extraction)	
1	0	S = Standard (postextraction, pre-operative)	
2	+	1 = Defect Series 1	
18A OR	0	2 = Defect Series 2	
S	0		
1	+		
2	+		

CHAPTER IV

RESULTS

Fifteen artificial bony defects were created manually in the mandibles of 10 human cadavers using a #6 round bur and slow speed hand-piece. Of these defects, one was lateral, two were furcal, and twelve were periapical lesions, (Table 4). Each type of mandibular dentition, from central incisor through 2nd molar, was altered and investigated. Radiographic, visual, and microdensitometric analyses were recorded of all defects with respect to involvement or non-involvement of cortical bone.

Of the twelve artificially created periapical defects, eleven were confined within trabecular bone. That is, they involved neither the cortical bone nor the junctional area between trabecular and cortical bone. All but one specimen were evaluated as having definite periapical radiolucencies when the radiographs of defect series #2 were examined, as only specimen #26A had a questionable defect at this stage. Specimen #13, which had definite destruction of bone at the junction of trabecular and cortical bone, was also evaluated as having a definite periapical radiolucency at defect series #2. The lateral defect (specimen #6), was evaluated as having a questionable radiolucency at defect series #1 and a definite radiolucency at defect series #2. Both furcation defects, (9A and 9B), were radiographically detected as having furcal destruction at defect series #1.

TABLE 4
CREATED DEFECTS

SPECIMEN #	TOOTH #	DEFECT
6	20	LATERAL
9A	30	FURCAL
9B	31	FURCAL
13	27	PERIAPICAL
14	22	PERIAPICAL
16	20	PERIAPICAL
17A	23	PERIAPICAL
17B	21	PERIAPICAL
18A	25	PERIAPICAL
18B	24	PERIAPICAL
23	22	PERIAPICAL
24A	22	PERIAPICAL
24B	20	PERIAPICAL
26A	20	PERIAPICAL
26B	22	PERIAPICAL

Three of the twelve periapical defects were evaluated as having questionable radiolucencies when viewing the "original" (OR) radiographs. Four were evaluated as having questionable radiolucencies on the "standard" (S) radiographs and one was evaluated as having a definite radiolucency on the "standard" radiograph.

The evaluation of radiographic defects was reversed on only one specimen. Specimen #9B was evaluated as having a possible furcal involvement on the "original" radiograph and no radiographic lesion on the "standard" radiograph.

All of the specimens were examined through a dissecting microscope and each was evaluated as to the extent of the artificially created bone defect. The lateral defect was confined to trabecular bone, as were eleven of the twelve periapical defects, (Table 5).

Microdensitometric analyses demonstrated definite change in radiodensity in the artificial defects produced in the periapical areas. Alterations as small as one millimeter were detected visually and radiographically and corroborated by the microdensitometer analysis. However, microdensitometer values within a defect and between defects were of such great variation that quantitative values could not be determined. (Appendix D).

The Impregum impressions of the sockets served multiple purposes. They demonstrated a positive image of a negative space while showing contour, shape, and texture of the naturally occurring tooth sockets and the artificially created bone defects. They were valuable for demonstrating the dimensions of the alterations of sockets, accomplished with a #6 round bur and slow speed handpiece. The extent of the defects

TABLE 5
 EXTENT OF EXPERIMENTALLY PRODUCED PERIAPICAL
 AND LATERAL BONE DEFECTS

SPECIMEN #	TRABECULAR BONE WITHOUT CORTICAL BONE	TRABECULAR BONE AND CORTICAL BONE
6 (Lateral)	+	0
13 (Periapical)	0	+
14 "	+	0
16 "	+	0
17A "	+	0
17B "	+	0
18A "	+	0
18B "	+	0
23 "	+	0
24A "	+	0
24B "	+	0
26A "	+	0
26B "	+	0

Key: + = Yes 0 = No

could be seen and the change in texture of the lamina dura from a stippled surface to a smooth surface was created by the grinding. The three impressions of each specimen recorded the defect's progression both in volume and direction. Impregum was selected for its accuracy and stability in the time allotted for the experimentation.

CHAPTER V

DISCUSSION

Analysis of these data is in sharp contrast with work previously recorded by Bender and Seltzer, Pauls and Trott, Ramadan and Mitchell, Schwartz and Foster, and Wengraf. It is in agreement with work performed by Shoha, Dowson, and Richards, and LeQuire, Cunningham, and Pelleu. The data obtained strongly supports the concept that it is possible to visualize radiographically a periapical and/or lateral defect before it encroaches upon junctional or cortical bone in certain specimens of human mandibles.

These defects may have been recognized due to the following reasons:

1. Clinical radiographic technique, i.e. 90 KVP and 15 Ma was used to elicit a long grey scale with low contrast and high intensity and penetration of the radiographic images.
2. Ideal serial radiography was performed. The long axis of the tooth, the surface of the film, and the end of the collimator were paralleled so that the central ray intersected all three at right angles in both horizontal and vertical planes.
3. Appropriate source-object distance (long cone) and required clinical filtration were utilized to eliminate any discrepancies caused by long wavelengths or divergent rays (penumbra effect) from the X-ray generating source.

4. Ideal film-object working distances were allowed due to the absence of overlying soft tissues which often affect positioning of films in the oral cavity.
5. Ideal tooth-film positioning was maintained to eliminate overlapping, elongation, and foreshortening of the radiographic image.
6. Multiple specimens were used to demonstrate variations between and/or within specimens. These variations include density of cortical plates, amount of trabeculation, size and position of marrow spaces, contour of the mylohyoid ridge, and consistency of the lamina dura.
7. The defects were created through the sockets and not through sectioned cortical plates of specimens. This approach most closely simulates the destructive paths through which naturally occurring periapical lesions progress.

The specimens were analyzed by visual, radiographic, and microdensitometric methods to maintain the integrity of each separate analysis.

Naturally occurring or artificially created periapical defects may be misinterpreted for a number of the following reasons:

1. There is no prior radiographic history available to compare changes which may appear on the present film.
2. The use of lower Kvp and Ma may not produce a grey scale of sufficient gradations to display extremely subtle variations in radiodensities.
3. Improper vertical and/or horizontal angulation of the X-ray beam in relation to the axial planes of the object (i.e.

tooth), and/or distortion of the film packet may alter the radiographic image by elongating, foreshortening, or overlapping anatomical features or otherwise distort the radiographic image including that of the periapex.

4. The subject's calcific patterns and bony architecture may mask early pathosis thus preventing the dentist/diagnostician from recognizing early signs of the disease process.
5. Radiographs of patients with a periapical lesion and naturally occurring large marrow spaces may not exhibit a sharp delineation of the lesion from the marrow spaces. This may give the appearance that the lesion is a naturally occurring marrow space.
6. A periapical lesion may progress in a lingual direction, i.e. specimen #18B, and thus be masked by the root's radiopacity. The lesion may not be detected radiographically until it has progressed beyond the outline of cementum.
7. Some lesions will not be detected until reaching junctional bone or cortical plates because of the radiodensity of overlying hard tissues and of the bone itself.
8. The presence of a periapical lesion must be interpreted by the human eye and thus it becomes a subjective opinion. A microdensitometer analysis requires two identically positioned radiographs be taken at different time intervals to establish that bony changes have occurred as illustrated by changes in radiographic densities.

Clinical implications from this study may be extrapolated as follows:

1. Lesions as small as 1 mm. in greatest dimension may be detected by the clinician regardless of bone structure involved. Those lesions solely confined within trabecular bone may be identified using serial radiography and noted clinical symptoms conjunctively.
2. Radiographic thickening of the periodontal membrane may be interpreted as an early warning sign of periapical change and must be followed to diagnose probable apical pathosis when it occurs.
3. Ideal film positioning is critical when diagnosing periapical pathosis. Films must show clear and unobstructed views of the tooth apex and surrounding structures. When a periapical radiolucency is seen on a radiograph, all borders of the lesion must appear on the film to diagnose accurately the extent of the lesion and possible involvement with adjoining structures, i.e. adjacent root tips, sinuses, and nerve processes.
4. Films must be processed to produce archival quality images of the area in question. Underdeveloped or overdeveloped films may mask early periapical change which could be used to identify subsequent disease. Proper positioning of the film will aid in comparison with prior films of the areas reducing the radiographic variations caused by the operator.

5. Several films from different angles must be examined when determining signs of periapical pathosis. In multirrooted teeth, angled radiographs are essential to establish location and source of the pathosis. The question of which root or tooth is causing the radiolucency is vital for treatment of the disease. Rarely can periapical disease be properly diagnosed and treated from a single film. The benefits of appropriate additional films far outweigh the risks of additional radiation and cost to the patient.
6. It is beneficial to have prior films of the area in question to compare any radiographic changes which may have transpired over a period of time. Careful maintenance of patient records is essential and acquisition of prior films is most beneficial when treating periapical disease.
7. Radiographs in themselves are not sufficient for diagnosis of changing periapical conditions. Clinical symptoms, when noted, are important adjuncts in determining the true picture of the periapex and subsequent changes. It is quite possible that clinical symptoms and radiographic signs do not corroborate as integral parts to the diagnosis puzzle. Each part in itself does not illustrate the total picture until it is joined with all available parts.

CHAPTER VI

CONCLUSIONS

Fifteen artificial bony defects were created manually in the mandibles of 10 human cadavers using a #6 round bur and slow speed hand-piece. The defects consisted of one lateral, two furcal, and twelve periapical lesions. Each type of mandibular dentition, i.e. central incisor through 2nd molar, was altered experimentally and tested. Radiographic, visual, and microdensitometric analyses were recorded of all defects with respect to involvement or non-involvement of cortical bone.

Twelve periapical defects were created, eleven of which were confined within trabecular bone structure but did not encroach nor perforate junctional or cortical bone. These eleven trabecular bone defects were detected radiographically and could be identified as simulated periapical lesions from postexperimental radiographs. The single periapical defect involving cortical bone was also radiographically detected. The lateral defect, confined within trabecular bone, was present radiographically and diagnosed prior to cortical bone involvement.

Artificially created furcal defects, (in 1st and 2nd molars), were detected after the first stage of bone removal from the furcal area.

Periapical and lateral lesions, in the mandibles of human cadavers, were detected radiographically when the lesions were solely confined within trabecular bone.

These lesions did not involve junctional bone nor cortical plates. The factors which may have affected the detection of the lesions included both technical and biological concepts. The technical factors included careful clinical radiographic techniques and the microdensitometric analyses of each specimen. The biological factors were the anatomical condition of the cadaver mandibles and the operator's subjective visualization of the pathosis from the radiographs.

These findings may be applied to lesions in the jaw of living patients considering the fact that overlying soft tissues and lack of ideal clinical methods for serial radiography may hinder the dentist and/or investigator from perceiving such bony changes via the radiograph.

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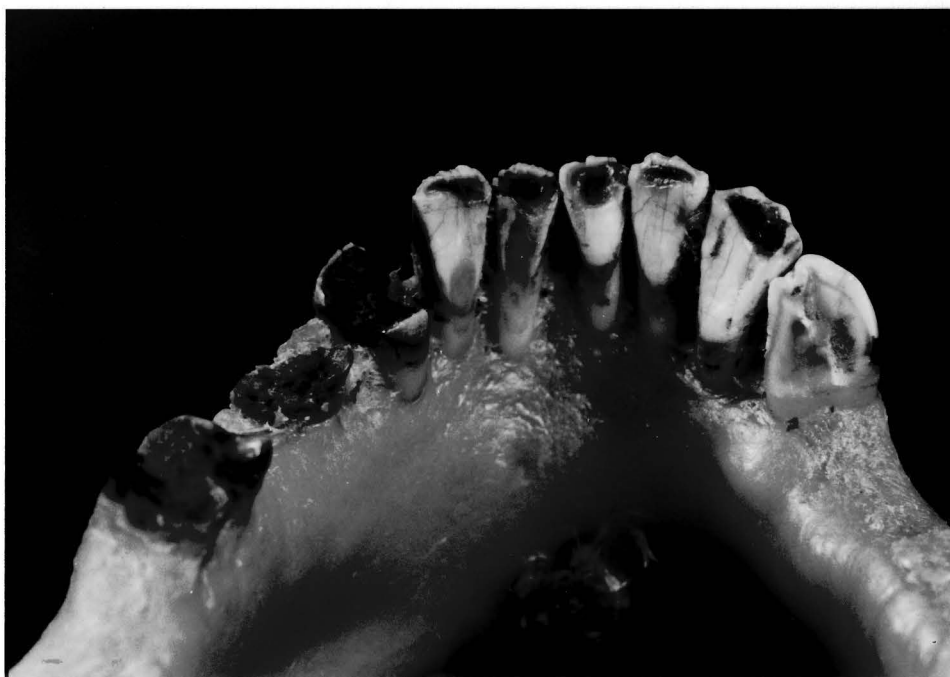
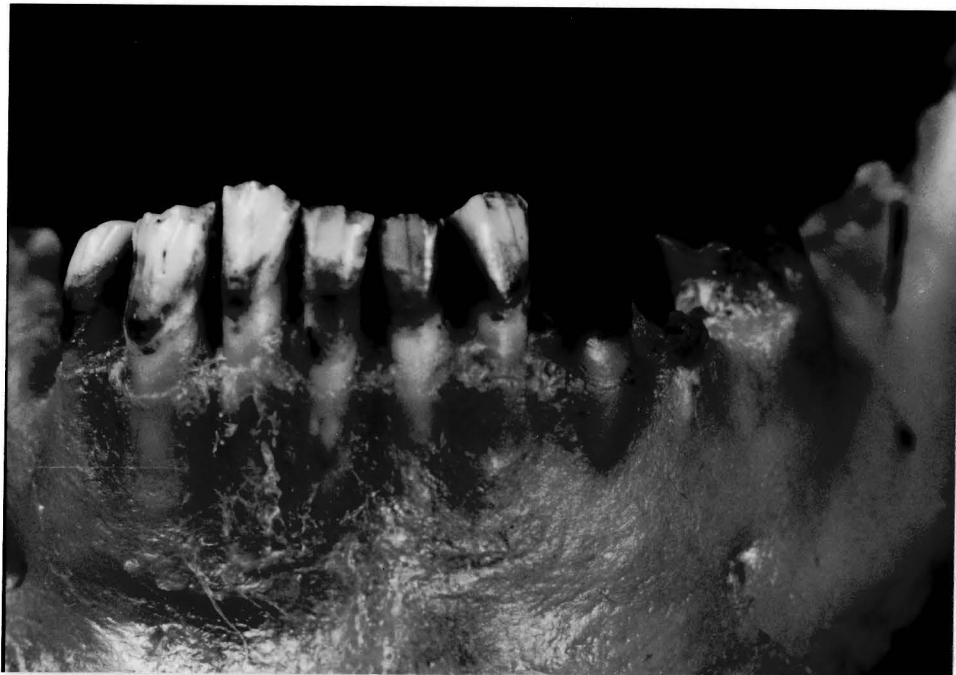
Volchansky, A. and Cleaton-Jones, P.: "Bony Defects in Dried Bantu Mandibles," Oral Surgery, Oral Medicine, and Oral Pathology 45:647-653, 1978.

Wengraf, Alex: "Radiologically Occult Bone Cavities," British Dental Journal 117:532-536, 1964.

APPENDIX A

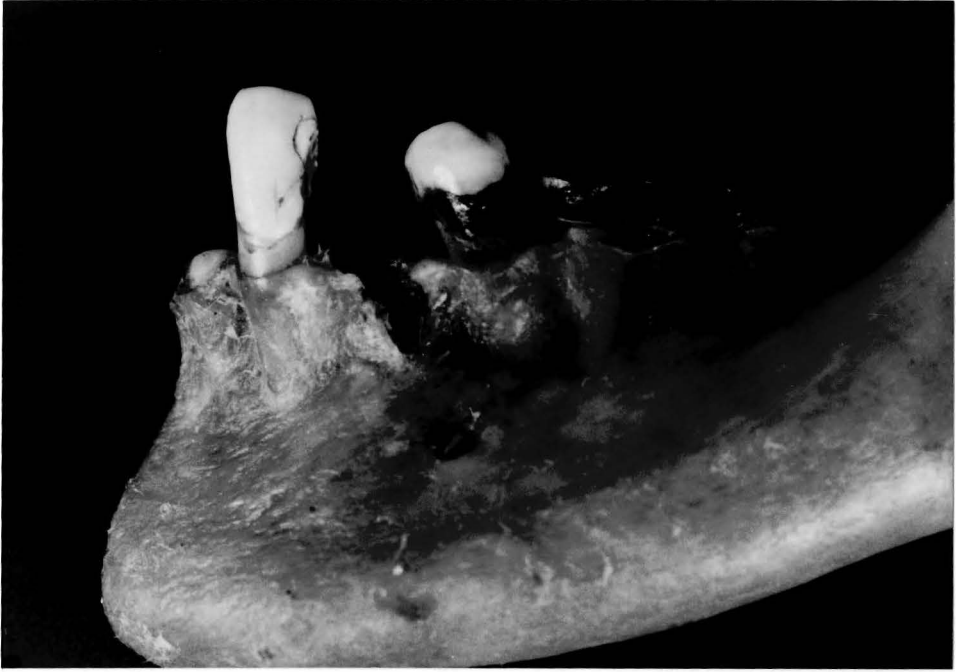
PHOTOGRAPHIC RECORDS OF INTACT GROSS SPECIMENS

#18B



PHOTOGRAPHIC RECORDS OF INTACT GROSS SPECIMENS

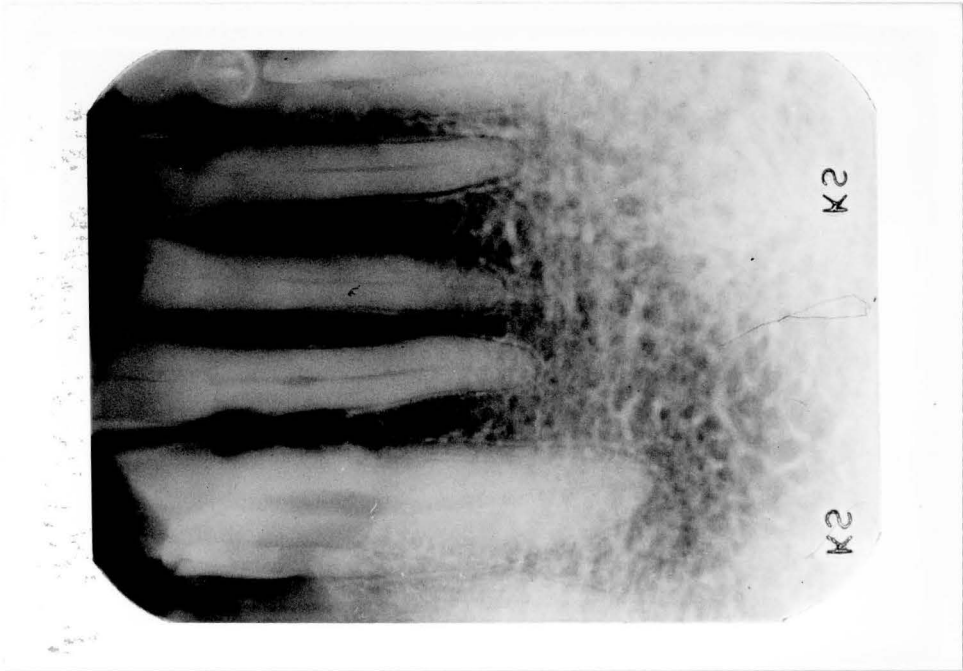
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APPENDIX B

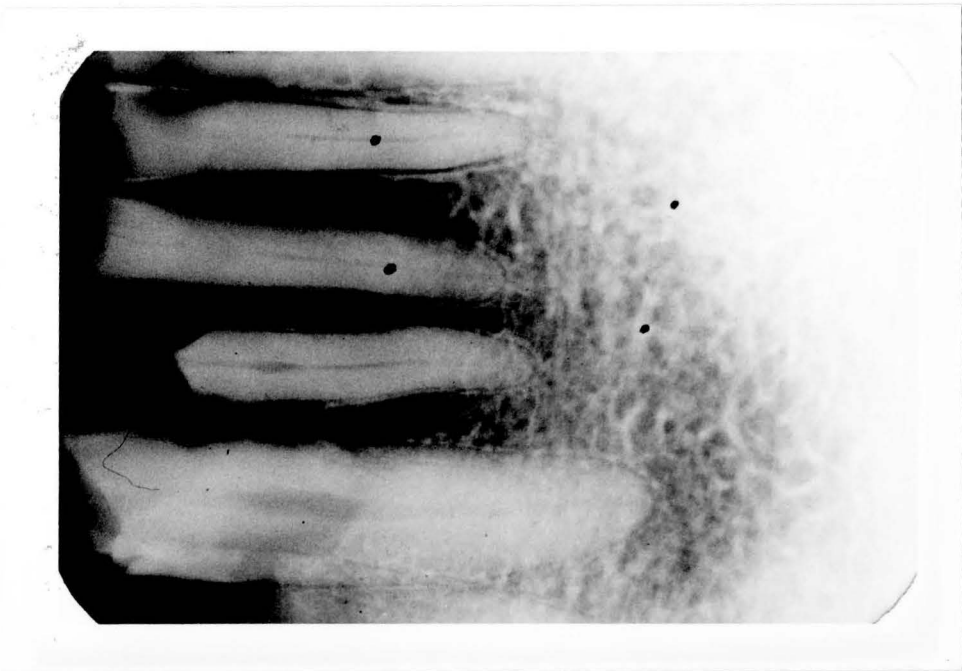
RADIOGRAPHIC RECORDS OF PERIAPICAL DEFECTS

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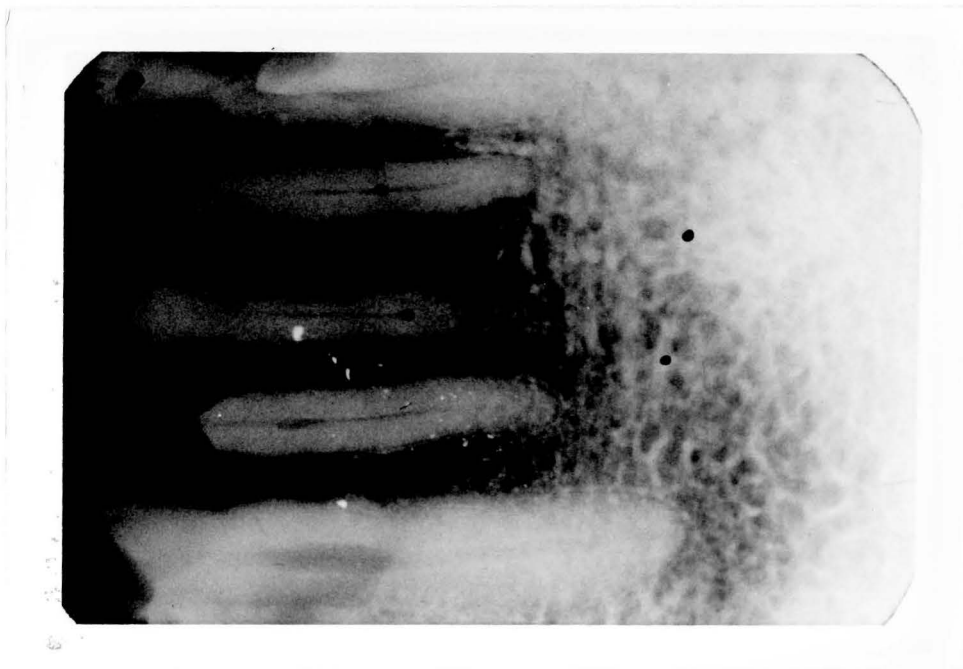


ORIGINAL

STANDARD

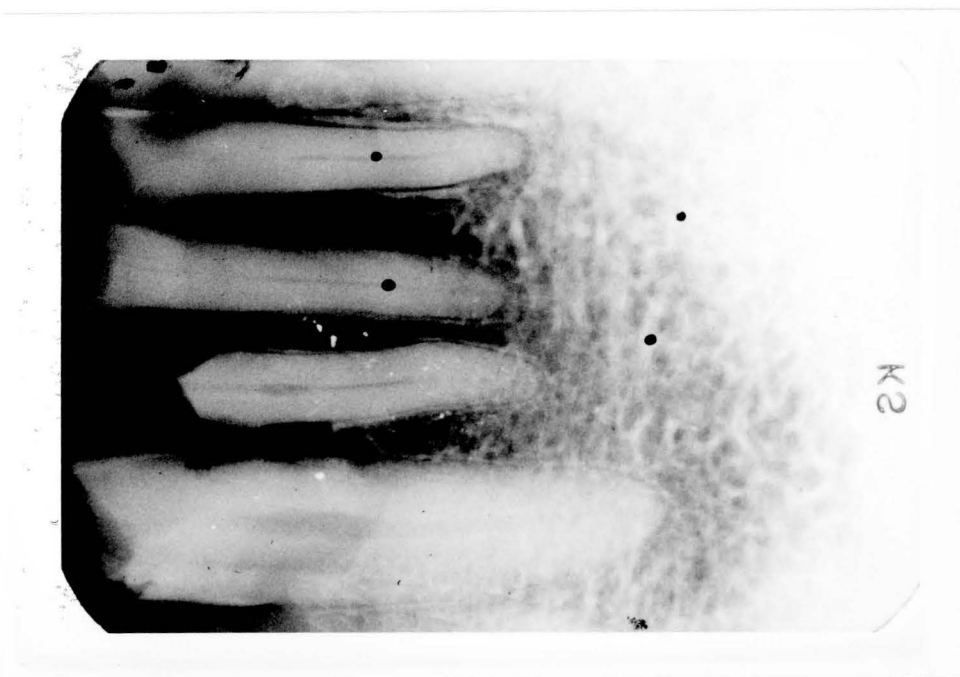


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DEFECT #1

DEFECT #2



RADIOGRAPHIC RECORDS OF PERIAPICAL DEFECTS

#24B



ORIGINAL

STANDARD



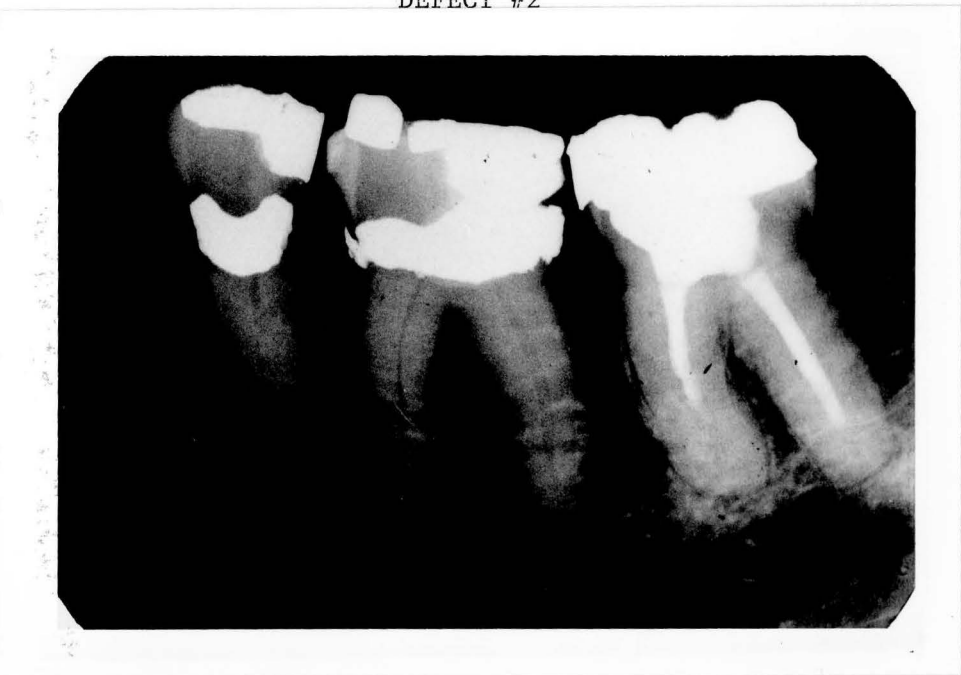
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APPENDIX C

DEFECT #1

DEFECT #2

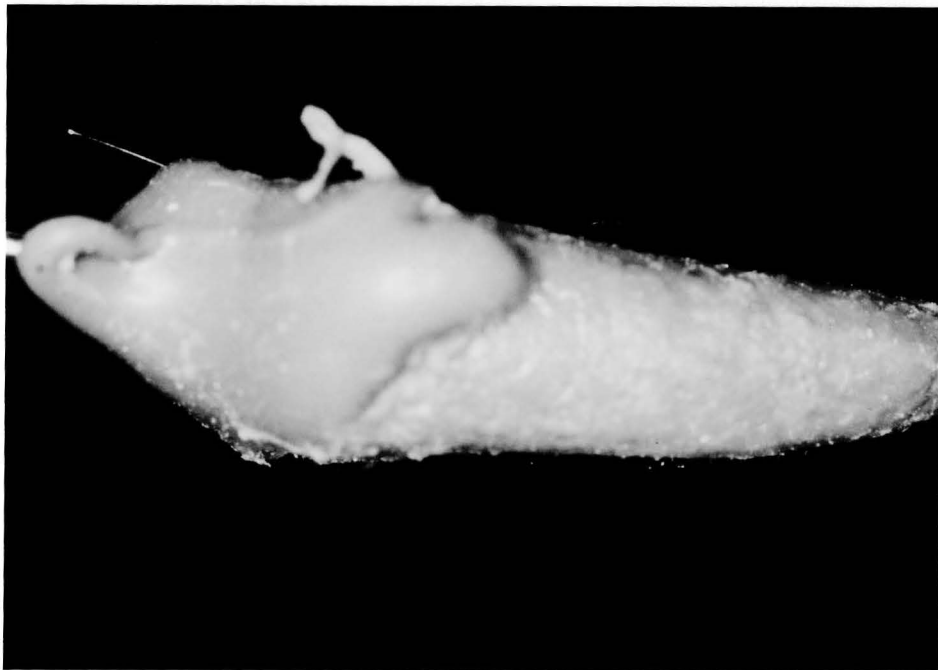


APPENDIX C

PHOTOGRAPHIC RECORDS OF IMPREGUM IMPRESSIONS

#18B

STANDARD



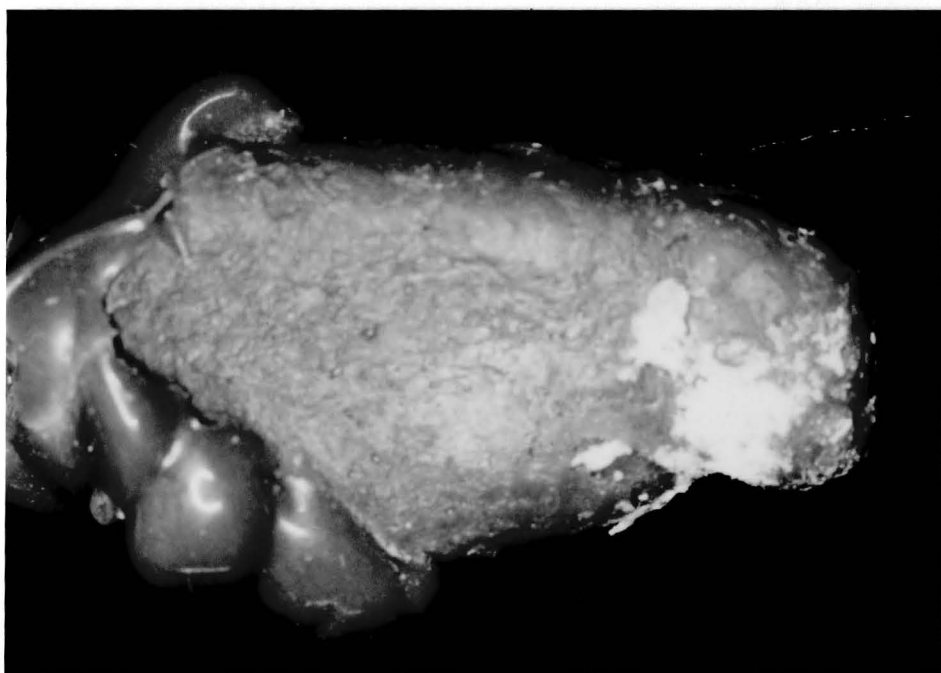
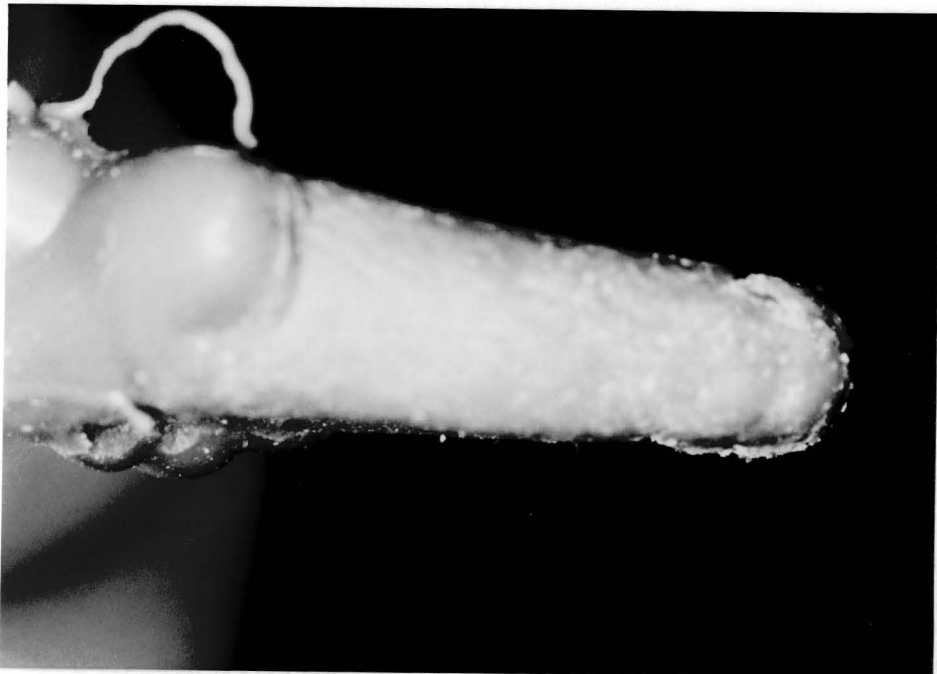
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DEFECT #1



#18B

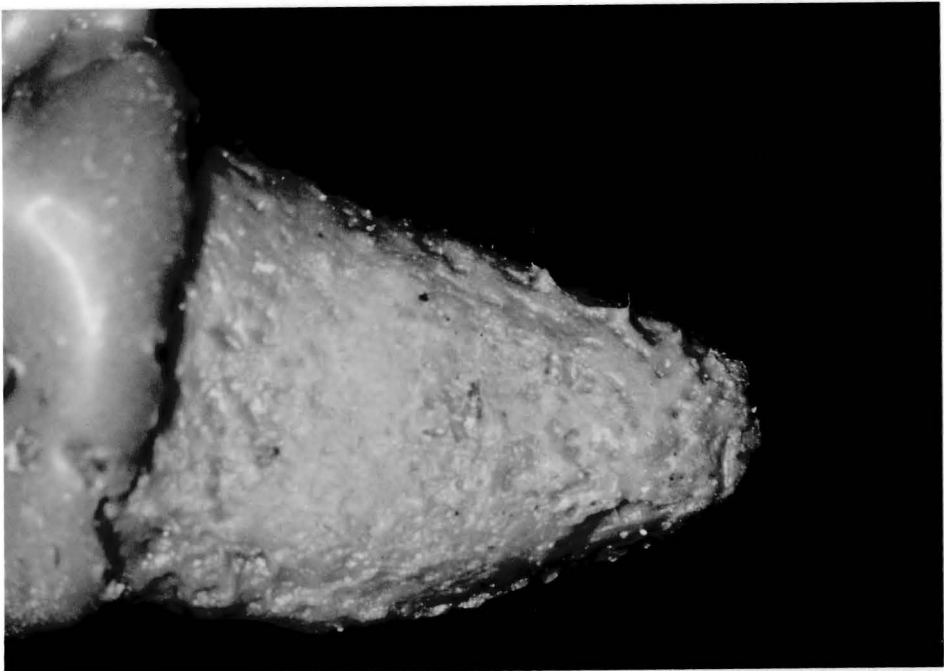
DEFECT #2



PHOTOGRAPHIC RECORDS OF IMPREGUM IMPRESSIONS

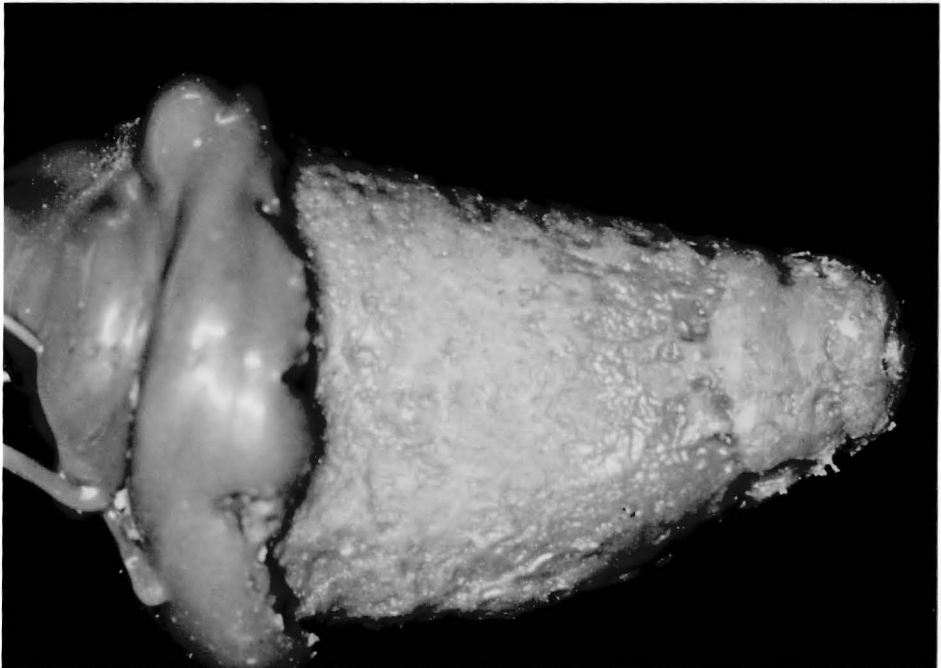
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STANDARD



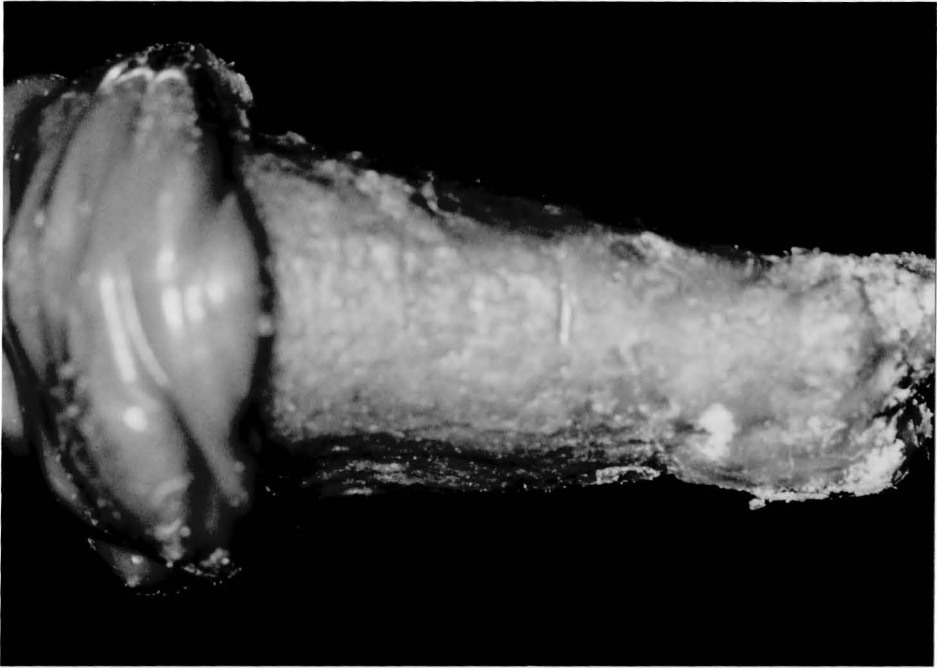
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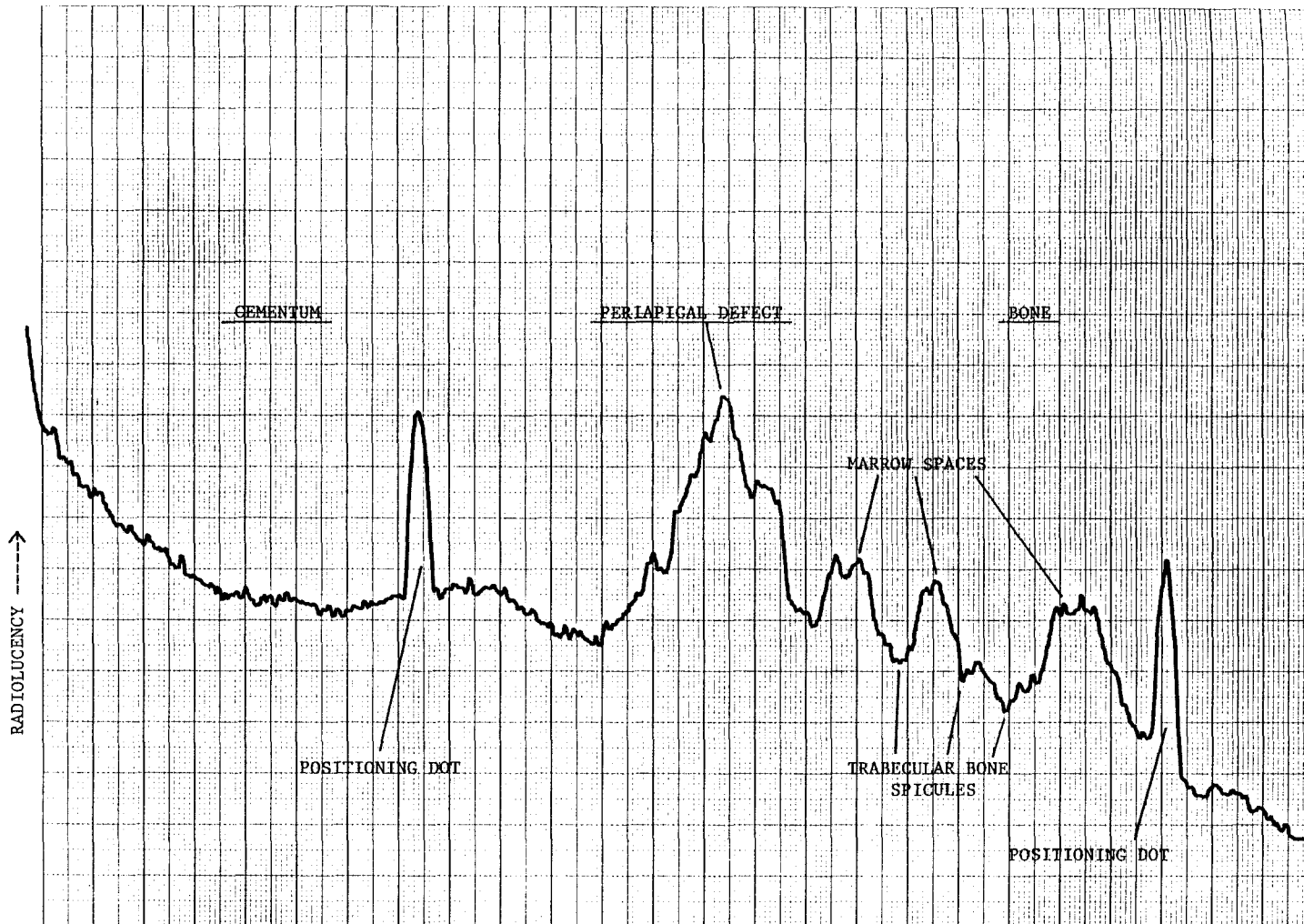


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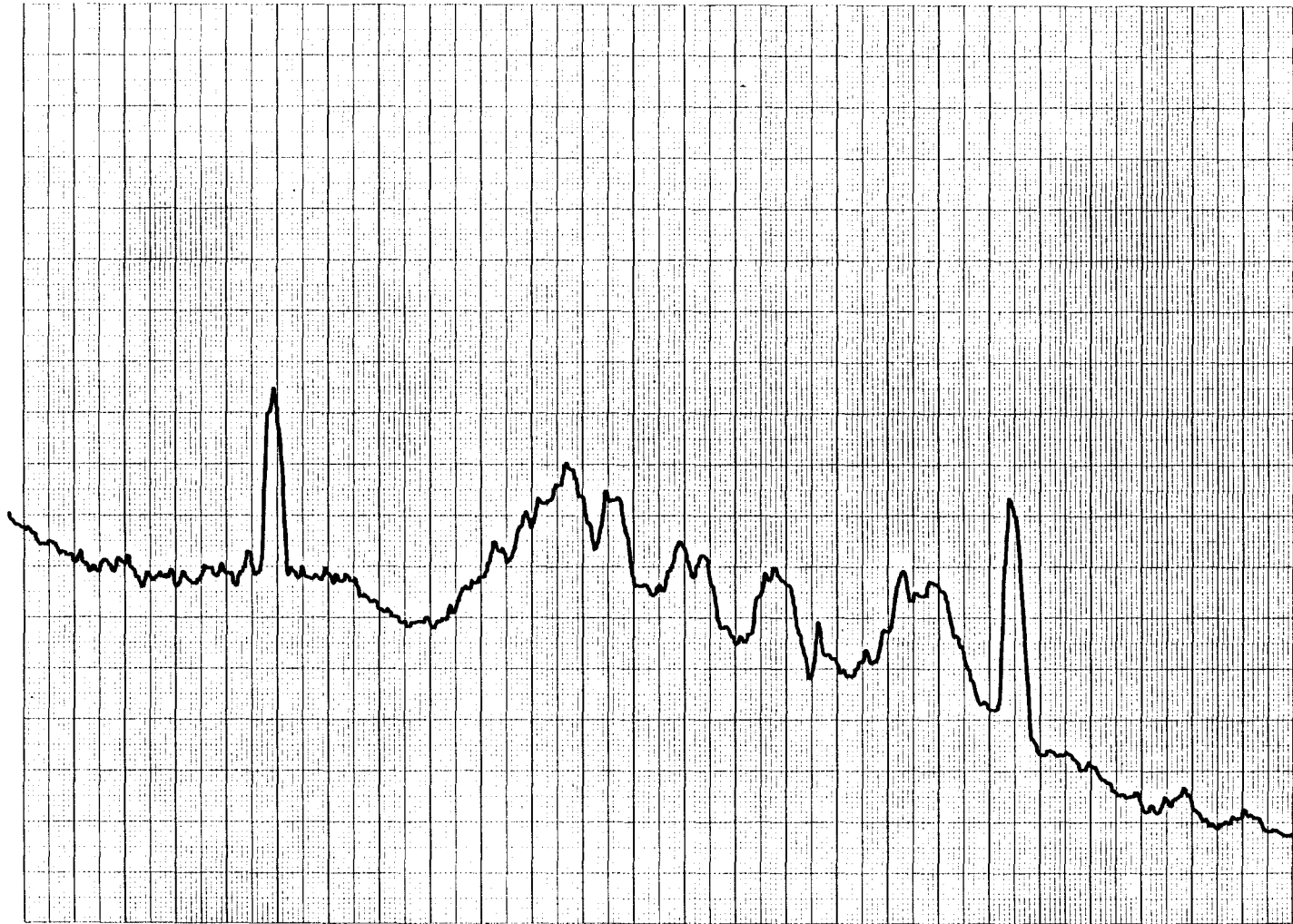


APPENDIX D

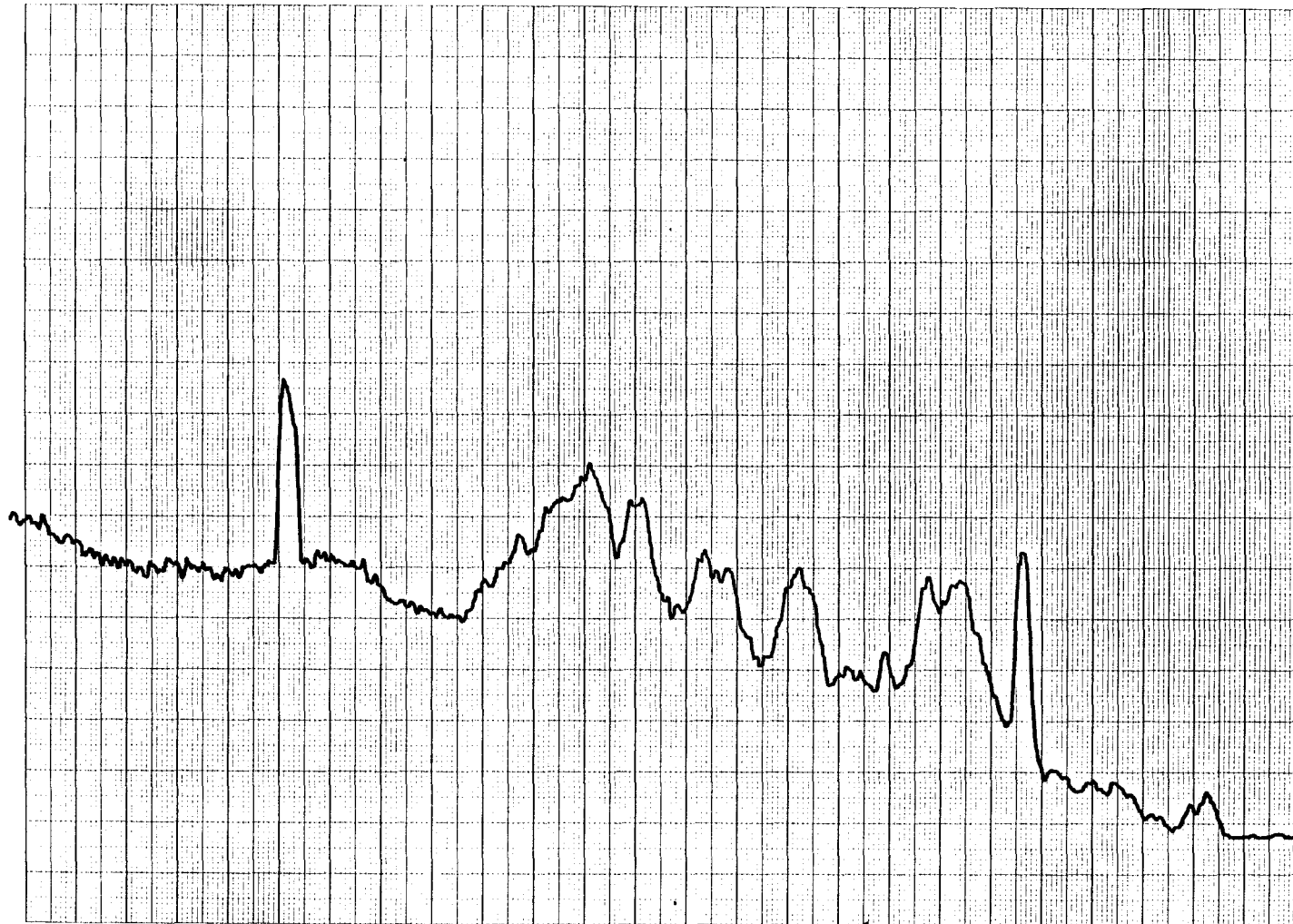


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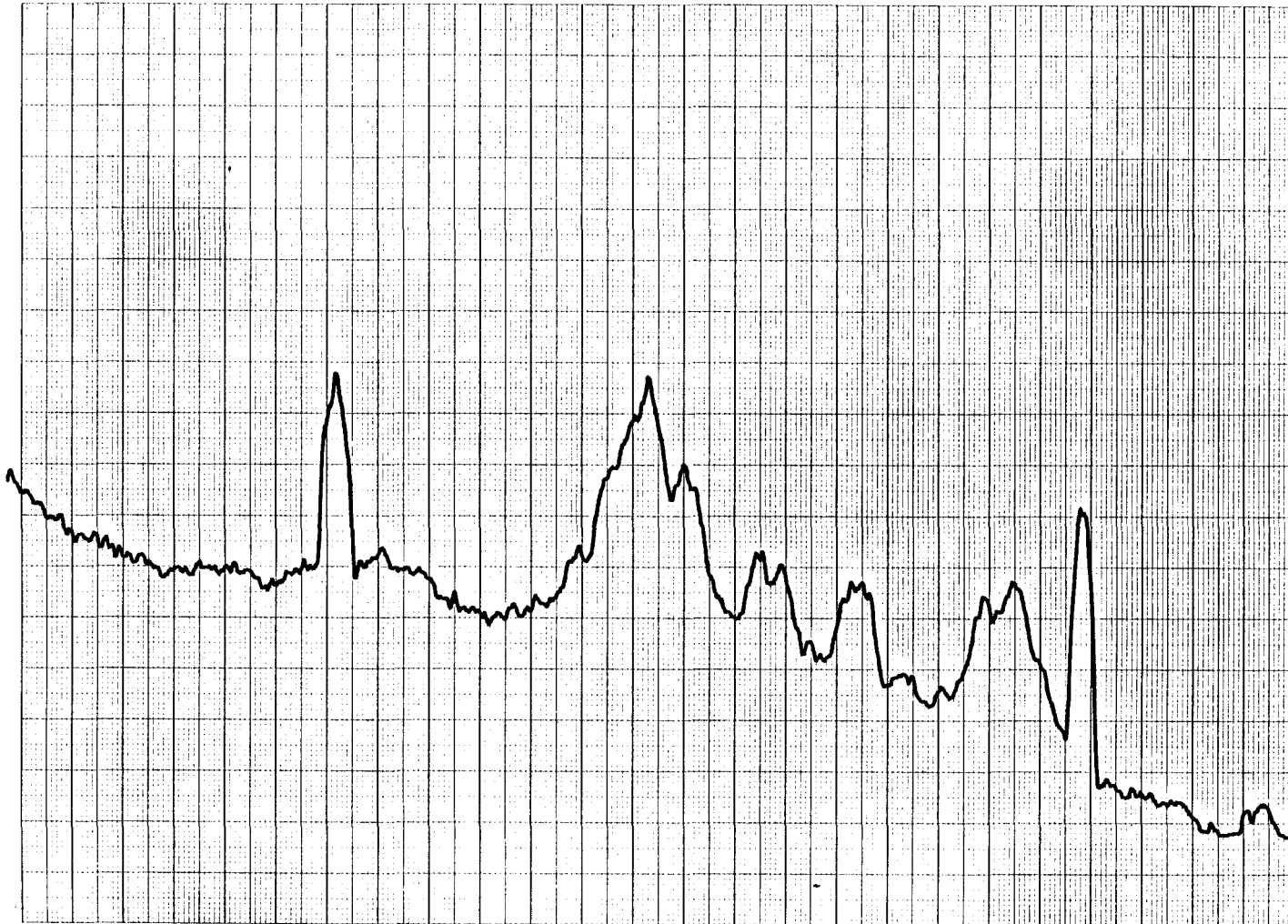
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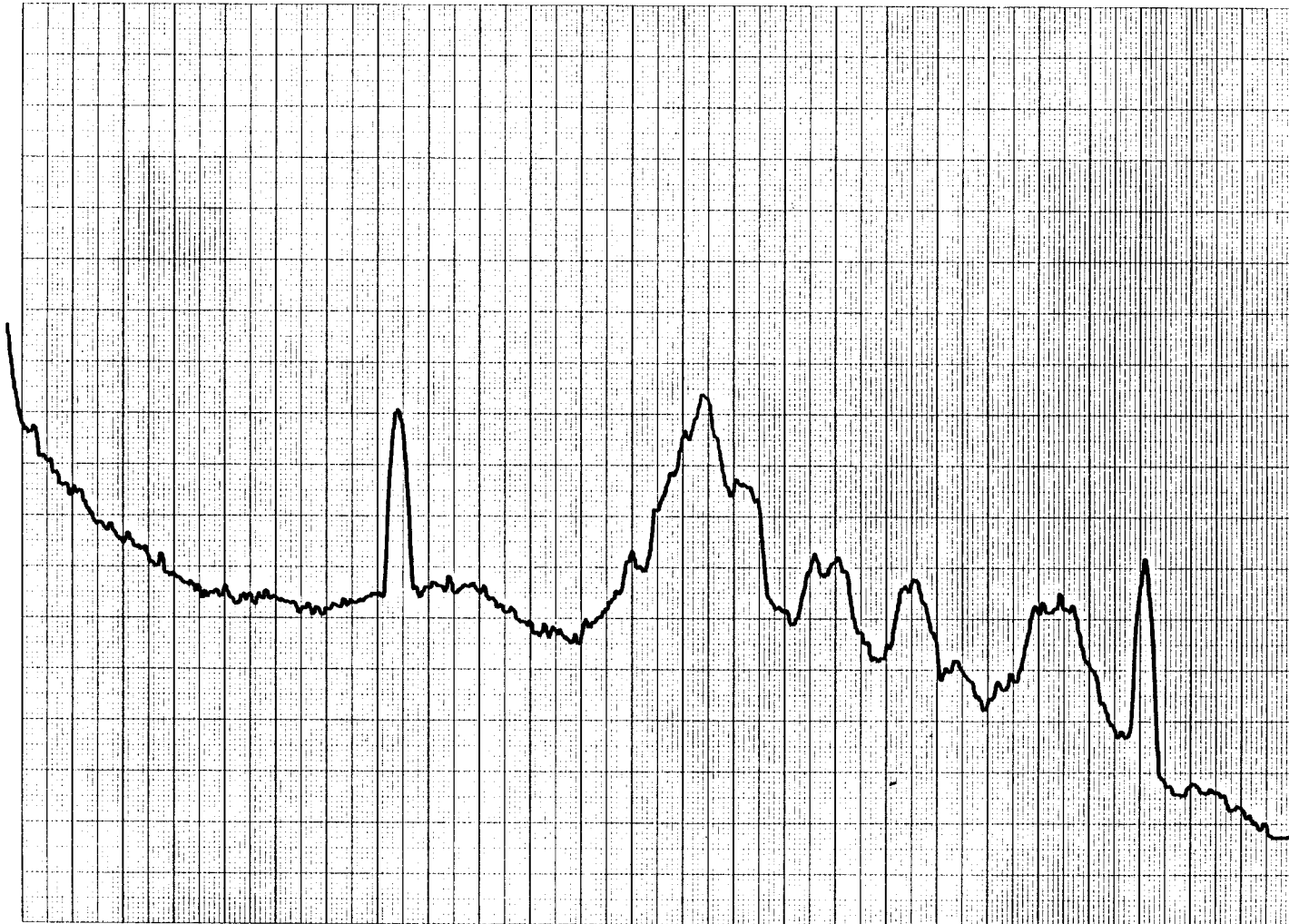
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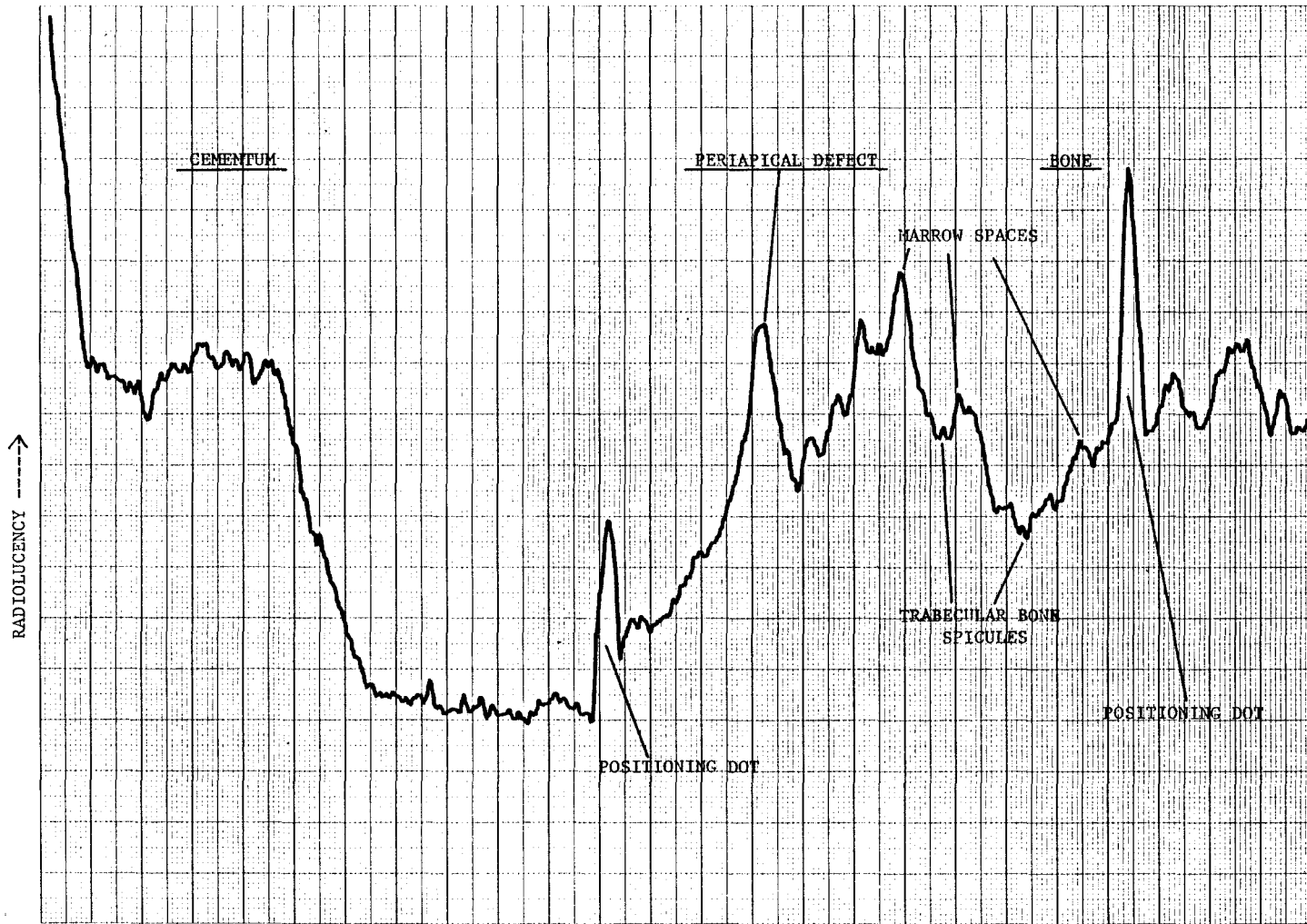
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#18 DEFECT - Series 1 (B)

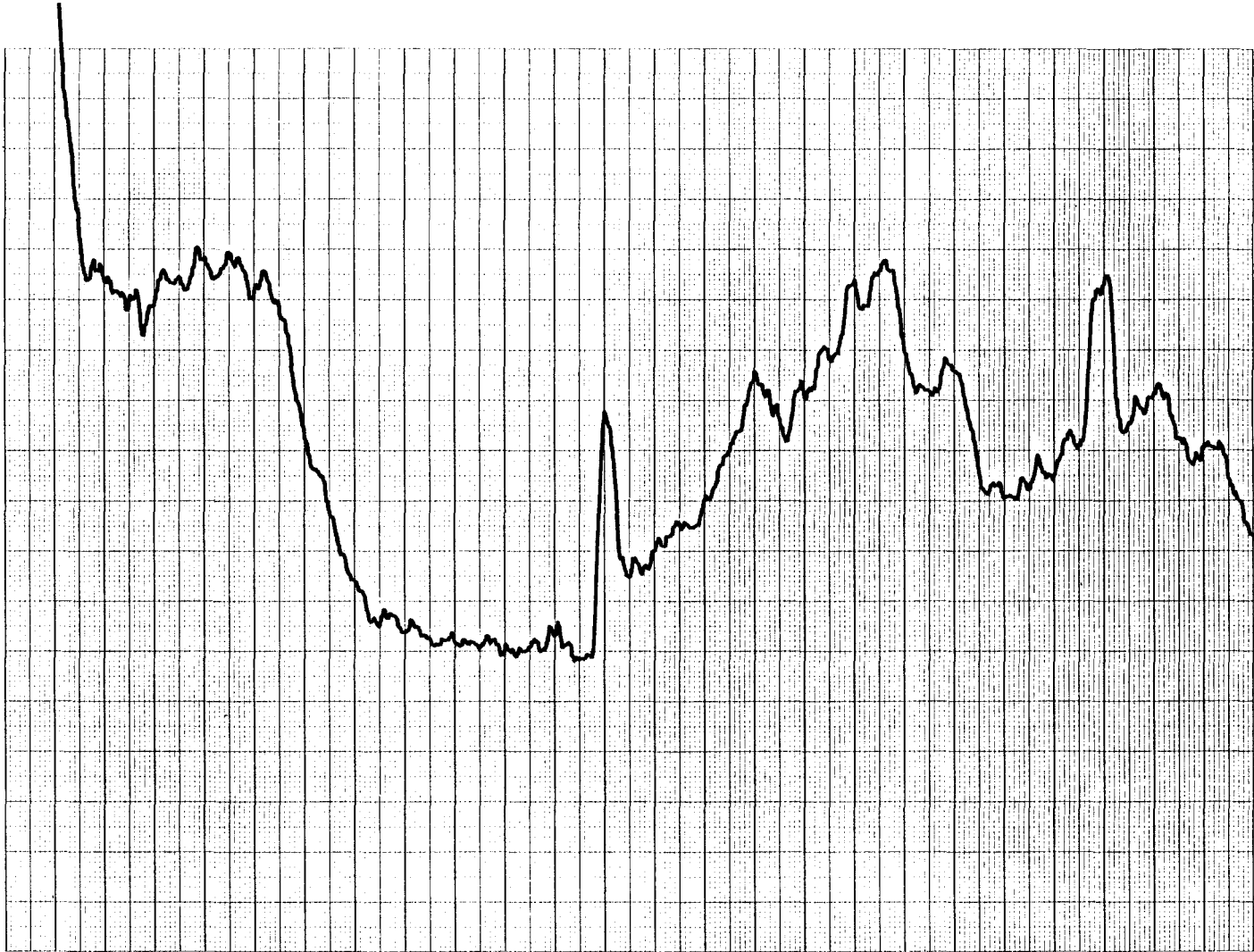


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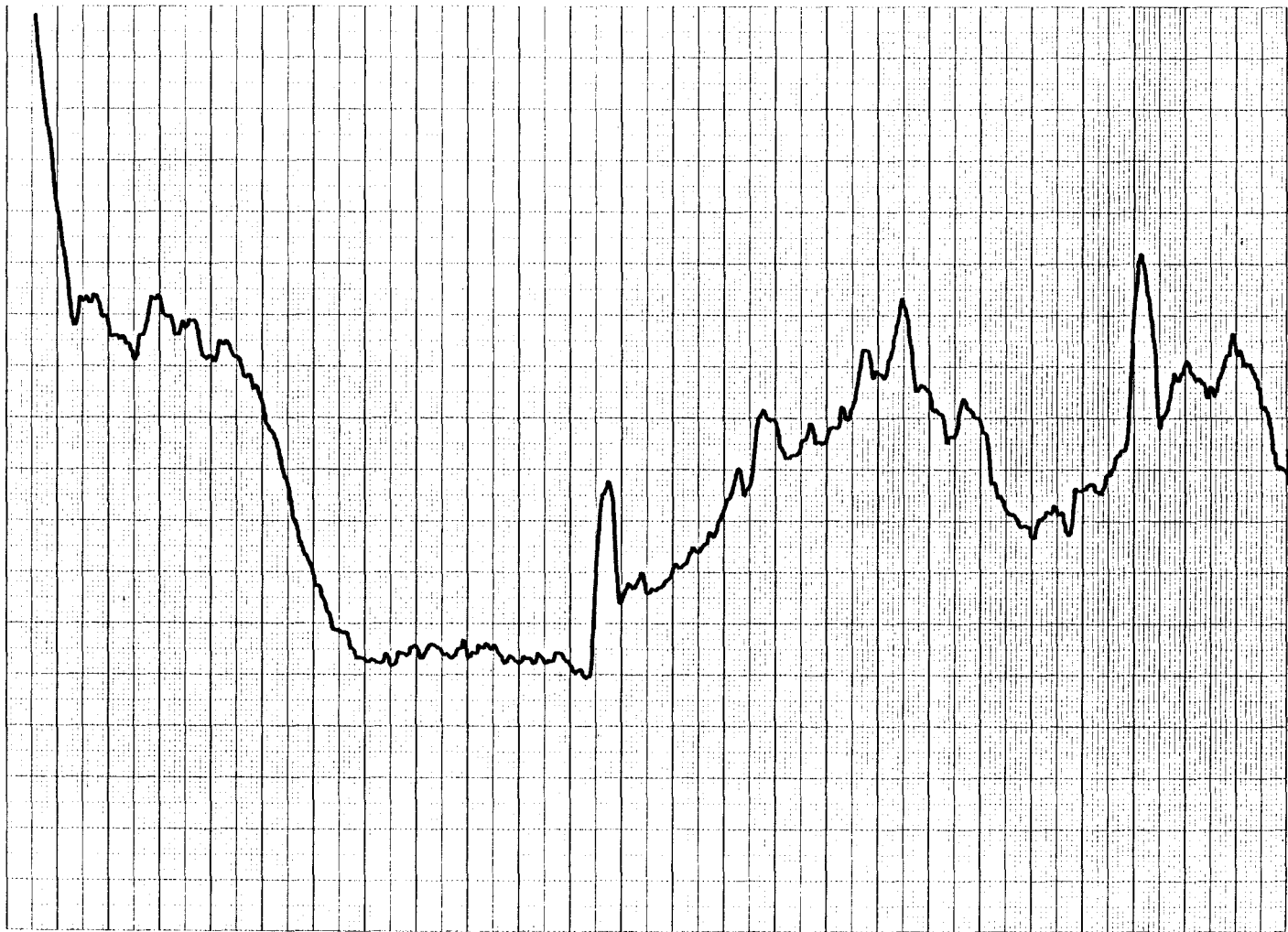


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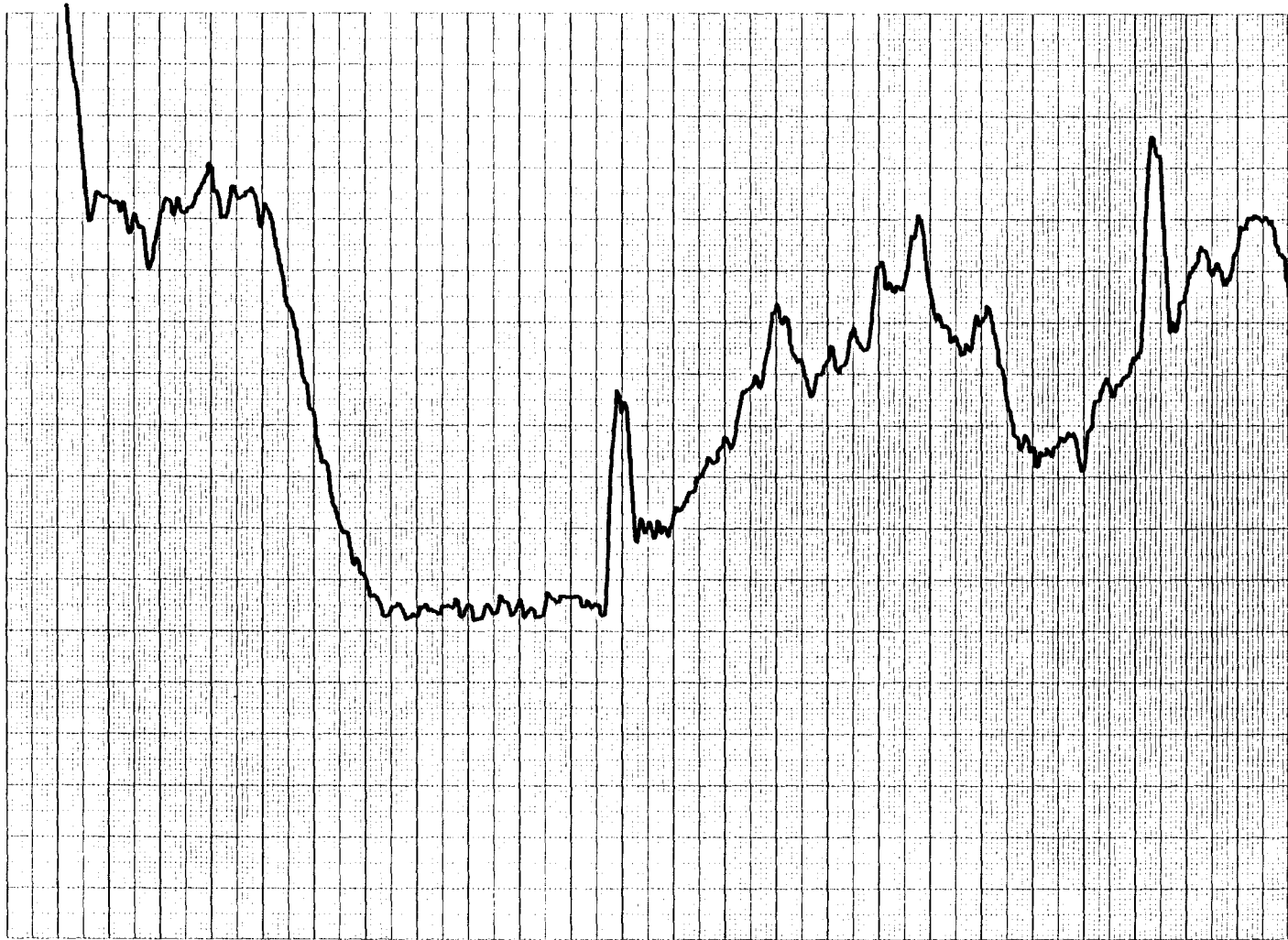
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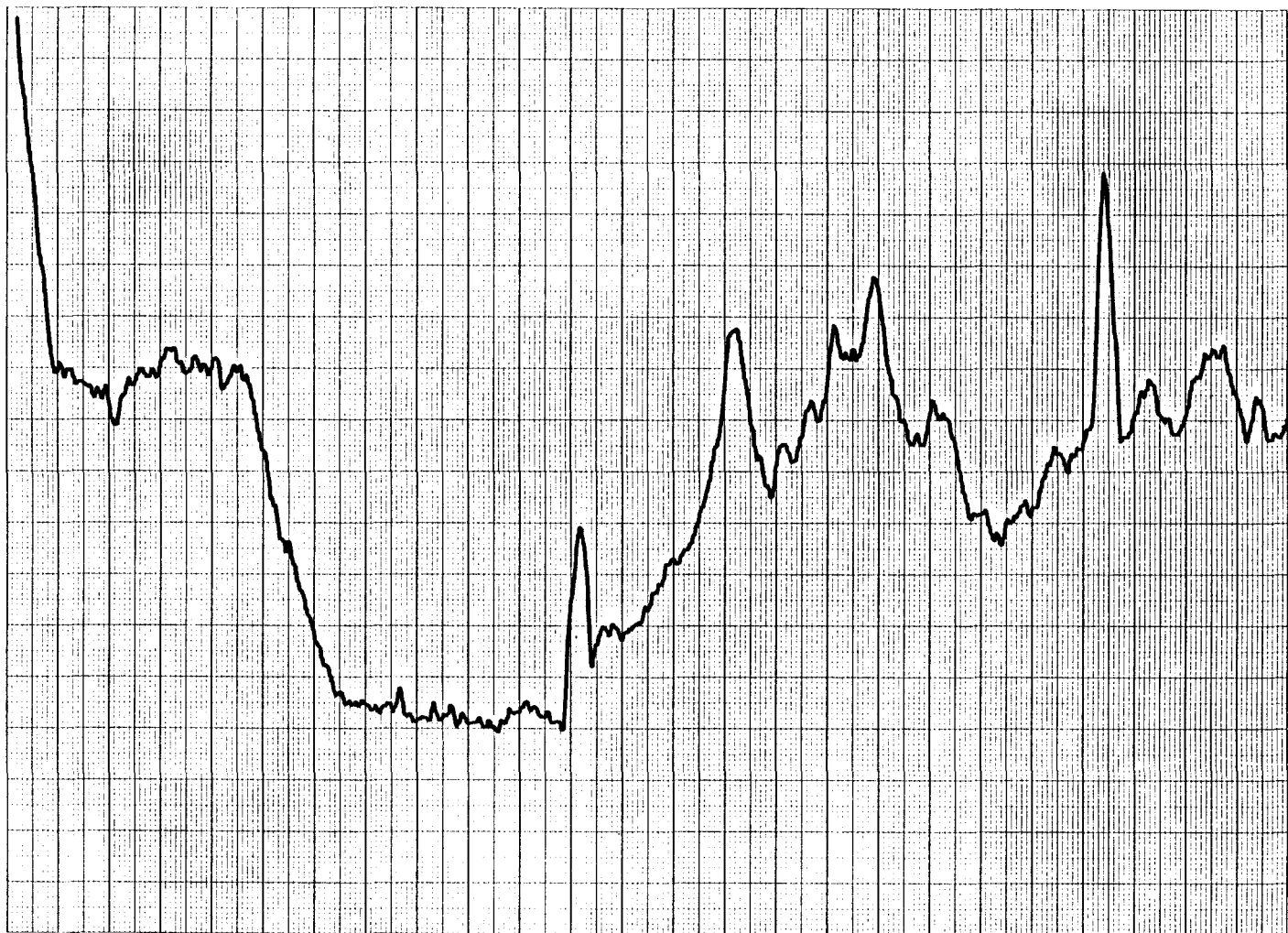
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#24 Post Extraction - Preoperative (B)



#24 DEFECT -Series 1 (B)

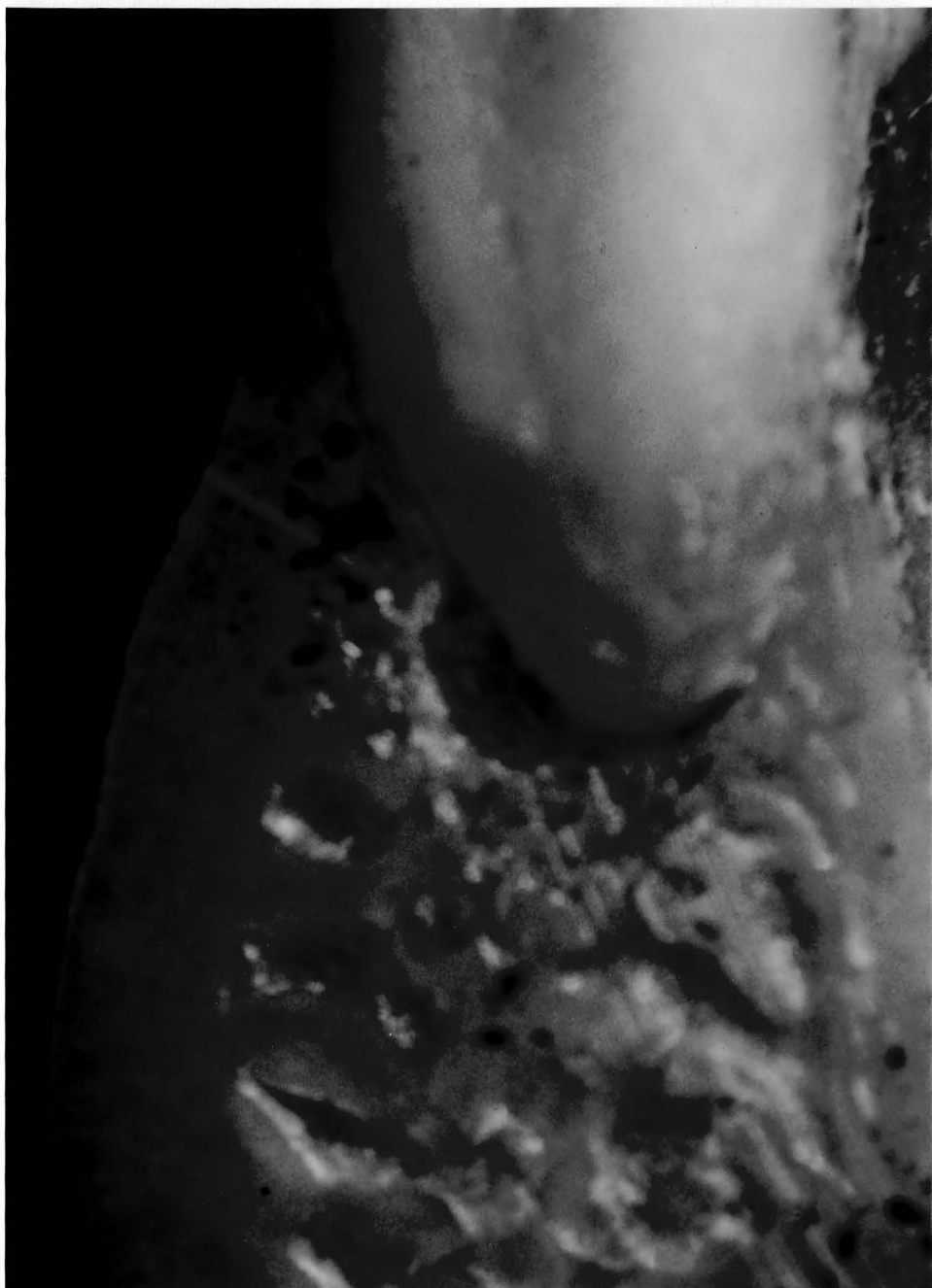


#24 DEFECT - Series 2 (B)

APPENDIX E

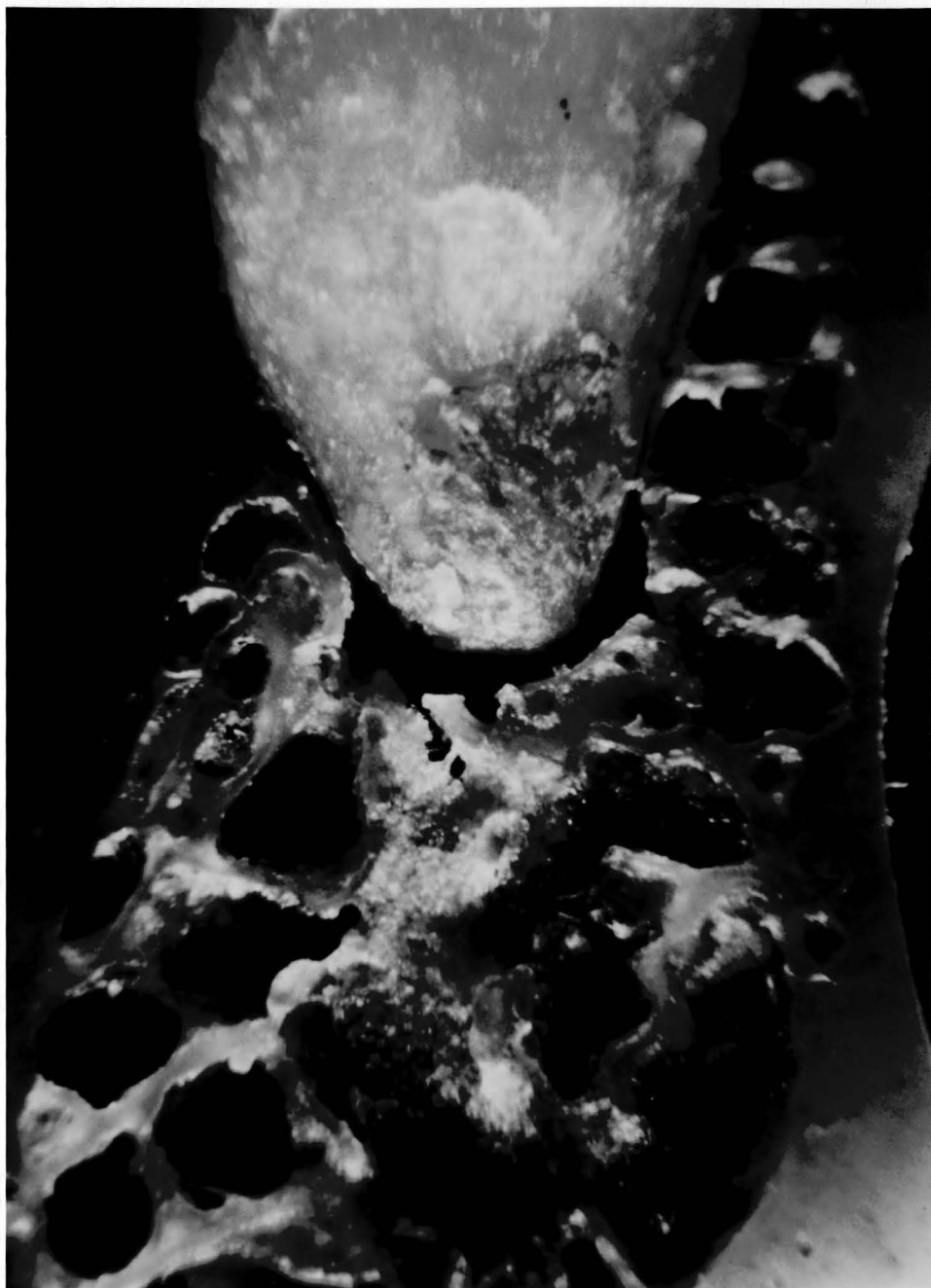
PHOTOGRAPHIC RECORDS OF SECTIONED GROSS SPECIMENS

#18B



PHOTOGRAPHIC RECORDS OF SECTIONED GROSS SPECIMENS

#24B



APPROVAL SHEET

The thesis submitted by Paul S. Valasek, D.D.S., B.S., has been read and approved by the following committee:

Dr. Thomas E. Emmering, Director
Associate Professor and Chairman,
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Loyola University of Chicago

Dr. Franklin S. Weine
Professor and Director of Graduate Studies
Department of Endodontics
Loyola University of Chicago

Dr. Joseph M. Gowgiel
Associate Professor and Chairman
Department of Anatomy
Loyola University of Chicago

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the dissertation is now given final approval by the Committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science in Oral Biology.

Date

April 15, 1985

Director's Signature

Thomas E. Emmering