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The Study of Tissue Reaction to a Magnetic Metal Implant

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**THE STUDY OF TISSUE REACTION
TO A MAGNETIC METAL IMPLANT**

by

Anthony Vernon Abati

**A Thesis Submitted to the Faculty of the Graduate School
of Loyola University in Partial Fulfillment of
the Requirements for the Degree of
Master of Science**

June

1961

DEDICATION

This thesis is affectionately dedicated to my wife Diane, in appreciation of her cooperation and enthusiasm which has made this work possible.

LIFE

Anthony Vernon Abati, was born in Hibbing, Minnesota, August 1, 1925.

He was graduated from Hibbing High School, Hibbing, Minnesota, 1942.

Upon graduation he enlisted in the United States Army Air Forces and served as an aerial gunner with the Twentieth Air Force during World War II. He was honorably discharged from the United States Air Forces in March 1946.

From 1946 to 1948 he attended Hibbing Junior College, Hibbing, Minnesota, in the pre-dental curriculum. In September, 1948, he began his dental education at Loyola University School of Dentistry, Chicago College of Dental Surgery, Chicago, Illinois, and received the degree of Doctor of Dental Surgery in June of 1952.

Following graduation he maintained a private practice of general dentistry in Virginia, Minnesota until September of 1959.

In September 1959, he began a two year graduate program at Loyola University leading to a Master of Science Degree in Oral Anatomy.

On December 13, 1960, the author was selected as resident Oral

Surgeon in the Department of Oral and Plastic Surgery of the Cook County
Hospital, Chicago, Illinois.

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CHAPTER I

INTRODUCTION

For many years, man has attempted to replace missing parts of bone with grafts and metals. This Thesis deals with the struggle and search by medical science to find suitable materials which can be used by the implant prosthodontists to help the dental cripple who can't adjust to conventional dentures.

The specific aim of this investigation is to make available detailed information useful to understanding of tissue reaction as well as the feasibility for use of magnetic implants in oral prosthesis. Should such findings prove favorable such implants may be recommended for prosthesis in human subjects. This may be particularly useful when the conventional structures may be inadequate.

CHAPTER II

REVIEW OF THE LITERATURE

A. CURRENT STATUS OF IMPLANTS

The feasibility for use of metal implants in living tissues has always been a controversial subject, due mainly to the lack of knowledge of living tissues and materials. Implants, up to the time of Lister's work on antiseptis in 1860, had little or no chance of success due to infection without even considering the type of material that was used. Even after the time of Lister, many metallic implants failed because the physiology of bone and the reaction of body fluids to various metals was not well understood.

In the year 1930 technicological science made the discovery of new materials for implants, such as the stainless steel alloys and plastics. Thus, it has been only in the past thirty years that implant work has been feasible and stood a fair chance of success.

The most ancient specimen of a dental implant ever recorded seems to date as far back as the pre-Columbian era. According to Andrews, 1893, at the Peabody Museum of Harvard University, there is a skull

from this period discovered in Honduras in which an artificial tooth carved from a dark stone replaced a lower left lateral incisor.

Petronius, in 1565, was one of the first men to attempt the use of a metal appliance as an implant for closure of a cleft palate. He devised a gold plate for this purpose. The *J. de med Chir. et pharm. de Roux*, of August, 1775, contained the first recorded controversy regarding the use of metal as a surgical splint for the internal fixation of a fractured humerus.

Lambotte (1909) used various surgical prosthesis made of aluminum, silver, brass, red copper, magnesium and soft steel plated with gold or nickel. He said, "that copper is not well tolerated by tissues and should be rejected. If steel is covered with another metal, it corrodes much faster than when used alone, probably due to electrolytic action." This is the first recorded statement concerning unfavorable electrolyte and reactions by metal appliances in tissue.

Hey Groves (1913) using metal plates and screws in the fixation of fractures performed 100 experiments, 65 on the tibia and 35 on the femur of 81 cats and 19 rabbits. The plates used were 3/4" long and 1/8" wide, with two holes at either end. The screws were 3/16" long. To insure a good position of the bone, the holes were drilled, then the saw-cut made part way through the bone; the plates were screwed into position, and the division of the bone was completed. He claimed that nickel-plated

steel did not produce any irritating effects on the tissues; and that magnesium produced destruction of bone if it was in contact only with the cortex. His experiment was quite rudimentary and did not include microscopic examination.

Zierold (1924) conducted a study of the reaction of bone to gold, silver, aluminum, zinc, lead, copper, nickel, high carbon steel and low carbon steel, copper-aluminum alloy, magnesium, iron and stellite (formula for stellite is approximately 58 per cent cobalt, 35 per cent chromium and 4 per cent tungsten.) Under ether, five series of normal dogs were operated on.

SERIES I. FIFTEEN DOGS: The middle third of the tibia was exposed, a hole was drilled through the cortex and a metal implant 5 x 8 x 0.5 mm was inserted in the hole, flush with the surface of the bone. In the control animals, the wound was closed after drilling of the bone, without implantation of a metal.

SERIES II. FIFTEEN DOGS: The knee joint was exposed and a metal implant 2 mm x 3 cm. was inserted flush with the articular cartilage.

SERIES III. FOUR DOGS: A 2 mm hole was drilled through the cortex of each rib and metal implants 2 x 4 x 0.5 mm were inserted flush with the surface of the rib.

SERIES IV. FIFTEEN DOGS: A metal disk about 2 cm. in diameter in the

shape of a bottom was inserted in the mid temporal region of the skull.

SERIES V. FOUR DOGS: Using the fifth, sixth, seventh, eighth and ninth ribs a metal implant 1.5 x 0.5 x 0.5 cm was inserted in the same manner.

At the end of four weeks the specimens were removed and roentgenograms taken. Zierold reported that low carbon steels and high carbon steels produced extensive bone necrosis and were the most irritating of any of the metals tested. Zierold concluded that gold, aluminum and stellite are readily tolerated by bone and tend to become encapsulated with but little hinderance to the reparative processes. They are inert metals, unaffected by the living cells and body fluids. Silver and lead are only slightly less tolerable to bone, but are easily corroded and evoke a slightly greater connective tissue response. Zinc interferes with bone regeneration and does not become encapsulated by it. Copper causes definite stimulation to bone production, some specimens suggest that it may be toxic to the tissue. Magnesium has little stimulant, if anything, it retards rather than accelerates bone production. Alloying copper and aluminum interferes with bone regeneration and tend to become extruded. Steel and, to a less degree, iron definitely inhibited bone regeneration. Steel, which is poorly tolerated and readily soluble, seems least suitable of all for bone prosthesis. In reference to the reaction of bone to stellite, Zierold concluded that it showed "the least departure from

the normal. "

Cretin and Ponyanne (1933) attempted to explain the cause of variable reactions of metals on bone on a basis of cellular stimulation. They operated upon guinea-pigs and placed metals such as aluminum, silver, copper, iron, magnesium, nickel, lead, and zinc in the bones. They studied the reaction of metal in the medullary cavity of a fracture. They found that all the metals excited some degree of destruction which retarded growth of bone. This action also was essentially independent of location whether the metal was placed in the medullary cavity or directly on the bone surface.

Jones and Liberman (1936) studied the reaction of bone to metal as a foreign body. Four alloys in the form of tacks were used for the investigation. One was composed of vanadium steel, (vanadium is approximately 58 per cent cobalt, 35 per cent chromium and 4 per cent tungsten, the balance of the ingredients are iron, carbon and impurities). The other three alloys: the first is high in chromium content with nickel entirely absent is designated as nickel-free rustless steel. The second alloy is low in chromium content and high in nickel, the proportion about 1:3 is termed high nickel rustless steel. The third is high in chromium content and low in nickel, the proportion being about 2:1, it is called low nickel rustless steel.

Using four dogs the tacks were placed in the following locations: low nickel rustless steel tack in the right tibia; high nickel rustless steel tack in the left tibia; nickel-free rustless steel tack in the right femur; vanadium steel tack in the left femur. The tacks were allowed to remain in situ for 30 days. Tacks of the same metals used in dogs were soaked in Ringer's solution and kept at body temperature for 30 days to serve as controls. They found through clinical and histologic studies that the amount of corrosion and precipitation of irritant particles of metal, was directly proportional to the magnitude of the foreign body reaction of bone. In the experiment chrome-nickel-free rustless steel was best tolerated by bone tissue.

Venable, Strock and Beach (1936) conducted a study based upon electrolysis as a variable factor in the reaction of bone to various metals. The radiuses of twenty-four dogs were used. The radius of right foreleg was fractured in all the animals and the left radius was not. In the control series of dogs two screws made of similar metal were placed in the bone where they would be bathed by the same electrolyte (body fluid) and where no electrolytic action would be expected. The following metals were used in this group: Chromium-plated screw, plain steel screw, vanadium steel screw, silver wire, silver-plated steel screw, copper nails, galvanized iron screw, chromium-plated steel screw, and vitallium

screws.

In the subsequent series of dogs, screws of the same metals were placed in duo in bone in different combinations to find whether or not there would be electrolytic reaction between them. The following metals were used in this group: Copper nail and steel screw, copper nail and galvanized iron screw, chromium-plated screw and copper nail, plain steel screw and chromium-plated screw, chromium plated screw and silver peg, plain steel screw and silver-plated copper screw, vitallium screw and vanadium steel screw, vitallium screw and galvanized iron screw, plain steel screw and brass screw, brass screw and galvanized iron screw, plain steel screw and vitallium screw, brass screw and chromium-plated screw, and a steel screw and silver-plated copper.

At the time the dogs were sacrificed the macroscopic changes in the tissues were noted; biochemical examinations of the tissues and tissue fluids, screws, liver and kidney were conducted. The bone tissue at the screw holes was removed, sectioned and examined microscopically. They concluded that:

- (1) It is not possible to differentiate accurately the different reactions of soft tissue and bone to metals, by macroscopic, microscopic and X-ray studies.
- (2) An electric force is generated when different metals are

placed in tissues.

- (3) Pure metals are inert.
- (4) Any single metallic appliance (alloy) containing a metal subject to the action of body fluids will cause some galvanic action.
- (5) It is the electrolytic action which causes the formation of irritating metallic salt solutions in the local fluids.
This leads to bone necrosis and foreign body reaction.
- (6) Pure metals only should be placed at a point least subject to the action of body fluids.
- (7) Alloys should not contain iron, as iron is subject to the action of body fluids.
- (8) The alloy of least reaction is vitallium (cobalt, chromium, and tungsten).

Campbell and Speed (1939) reported on the use of vitallium in fractures of bone in the following:

1. Use of vitallium in "acute" fractures.
2. Use of vitallium for delayed union or malunion of fractures.
3. Use of vitallium in ununited fractures.
4. Use of vitallium in "acute" compound fractures and
5. Use of vitallium plates following correction of deformity in old infected compound fractures.

No mention is made as to the number of cases reported or the surgical technique employed. Vitallium, because of its negligible electrolytic action, shown by the lack of inflammation in the tissue about the plates and the absence of absorption of bone about the screws, has made it a dependable material for the fixation of fractures even in the presence of gross infection.

Strock (1939) conducted a study using vitallium screws implanted into the alveoli of the jaw bone marrow. A 5/8" vitallium Venable screw was inserted into the tooth socket of a mandibular right central and into the maxillary right canine space of two human subjects; and into the mandibular left premolar area of two dogs following one month of normal healing. His findings of 8 months duration in the human patients revealed no discomfort except the inconvenience such as accompanies a loose tooth prior to exfoliation. The color of the mucosa was perfectly normal. In dogs, the screws were firmly in place after six months.

Stock concluded that vitallium implants threaded at one end and shaped at the other to receive porcelain crowns and other prosthetic devices and inserted under asptic conditions, offer a simple and secure method of temporarily replacing certain missing teeth.

Cameron and Henderson (1940) reported on a hundred cases in which metal was used for the fixation of fractures; and, concluded that vitallium,

because of its non-irritating qualities, has a definite advantage that some other metals do not possess. Vitallium plates and screws were removed after they had served their purpose showed no evidence of irritation to the surrounding bone or soft tissue. Discoloration and staining of structures, seen when some other metals were used was absent. After the plate had been thoroughly cleansed, it was impossible to distinguish them from new ones.

Bothe and Davenport (1941) did an experiment on the reaction of bone to metal and they drew different conclusions than Venable, Strock and Beach (1936). They felt that bone reaction was not closely correlated with the magnitude of potential differences, but rather remained characteristic for a given metal or alloy. Electrolysis is not the primary cause of unfavorable bone reaction. The primary cause is determined by the physical and chemical properties of the metal itself, the solubility and the degree of toxicity appear to be the chief factors involved.

Geib (1941) in his work with vitallium skull plates showed that the luster of the metal was unchanged and the screws were firmly embedded in the bone. Soft tissue had grown about the plate, up through the slots and small openings, and had completely grown together to form a fibrous covering. The tissue over the plate was firmly attached, yet peeled off the same as gelatin. No adverse tissue reaction was noticeable.

Geib (1941) using tantalum for skull plates found tantalum to be similar to vitallium. Sections of tissue next to the metal was found to be composed of a thin, shiny film of fibroblasts, free of edema or inflammatory changes. The tissue was not discolored, and the metal showed no sign of corrosion.

Pearce (1941) reported on two cases, one human and one dog, in which a vitallium tube was inserted into the bile duct and used as the bile duct tube. Vitallium was shown to be well tolerated and it was also thought to be superior to glass or plastic. Due to its strength, lack of electrolysis, and lack of tissue irritation recommend vitallium for bile duct tubes.

Strock and Ogus (1941 and 1943) reported two cases in humans of successful vitallium screw implants in upper anterior sockets. There was bony regeneration and tissue adhering to the screw. They noted that under masticatory stress the implants loosened. However, when taken out of function they became firm again.

Strock and Strock (1949) on a follow-up study of vitallium screws by Strock 1939, placed a 5/8" vitallium screw in the distal side of a canine socket of the right maxilla of a dog. One hundred fifteen weeks later this dog was sacrificed and the implant site examined histologically. Fine layer of connective tissue developed between the implant and the surrounding bone. In this "so-called" pseudoperiodontal membrane there was no down-growth

of the gingival epithelium as in periodontal socket formation. There was no actual attachment between the bone and the metal implant, yet the implant remained firm.

Herschfus (1955) in histopathologic studies of subperiosteal prosthodontic vitallium implants in three-month old dogs, showed no gingival tissue reaction or inflammation. Tissues around the abutments were firmly attached and the lamina propria contained dense collagenous fibers. The implants were retained by periosteal fibers that had proliferated through the meshwork. Six-month old implant in a dog showed the following:

Sections obtained from the area of the metallic insert revealed normal squamous epithelium which formed a cuff around the post. The epithelial pegs were prominent, but significant pathosis was absent in the stratified squamous epithelium. However, in the lamina propria a slight infiltration of lymphocytes and plasma cells was noted. The majority of the metallic insert sections failed to show any cellular reaction.

Bodine (1955) using one dog, reported on subperiosteal mandibular and maxillary premolar implants of ticonium. After one year, exploratory operations were made and numerous tissue sections were taken from around the posts, the screw and the cross bars. In the sections of tissue taken from around successful implant from the premolar area, connective tissue seemed to be against the neck of the implant tooth with no evidence of

epithelial down-growth. There was little inflammation present characterized by occasional inflammatory cells. This was due probably to food debris which accumulated around the neck of the implant tooth. The portion of the implants which were covered with tissue were bright on their underside. Only where the metal was exposed to oral fluids did salivary deposits form and discolor the under surface of the implant.

Herschfus (1955) discussed the implants of vitallium in bone of fourteen and sixteen months duration in dogs. His findings were as follows: Gross pathology revealed no evidence of an active inflammatory process. Microscopic pathology showed that immediately adjacent to the abutment stratified squamous epithelium of the gingival margin dipped slightly downward. The epithelium itself was slightly keratotic, quiescent and without significant abnormal changes. The lamina propria adjacent to the vitallium implant was composed of dense fibrous connective tissue matrix with a few chronic inflammatory cells. In the deeper layers the fibrous tissue was fused with the periosteum and the interstices of the vitallium meshwork firmly binding the implant. The bone itself, was composed of the usual osseous trabeculae separated by a marrow showing some fibrosis. A study of the sections failed to reveal evidence of foreign body or significant inflammatory reaction.

Herschfus (1957) in reporting a five year follow-up on a subperi-

steal prosthodontic vitallium implant in a dog reported the following:

Gross pathological studies revealed that the implant showed changes similar to those described in the 3, 6, 9, 14 and 16 month old dogs. No mention is made of the microscopic pathology.

Gross and Gold (1957) conducted an experiment to test the compatibility of cast-vitallium, wrought-vitallium, and austanium screws and plates for surgical use in completely buried implants. Surgical, gross, and histologic observations were made in a series of dogs over a period of from two to seventeen months. It was found that cast-vitallium and austanium plates and screws, combined or separate, were compatible with the soft tissues and bone.

Cobb (1960) using two oral vitallium implants which were mechanically secured and placed subperiosteally in the premolar area of the maxillary alveolar process of two dogs following extractions and alveoplasty reports that at the end of a three-month period there is no notable reaction of bone from pressure brought to bear by a vitallium implant mechanically secured, and no foreign body reaction of the soft tissues or bone.

Behrman (1960) reported on the tissue tolerability of metallic implants in both dogs and humans. The mandibular molars of dogs were extracted and the wounds were permitted to heal for four to five weeks. Four types of material were then implanted; two on bone; and, two in bone.

Subperiosteal materials implanted on bone were cast vitallium mesh frames and squares of tantalum mesh. Intrabony implants were two alnico V magnets; one coated with methyl methacrylate and the other was not. When the animals were sacrificed there was no significant macroscopic or microscopic evidence of irritation of bone or soft tissue. Each implant appeared to be surrounded by a thin, fibrous tissue capsule.

Behrman (1960) implanted platinum cobalt alloy magnets in the body of the human mandible. After six months duration he reported the magnets to be held firmly in place by bony growth around the edges of the implant.

The literature included many different types of oral implants that could be classified into three general categories:

- (1) Endo-osseous dental implants - the insertion of a pivot, a screw or a cage into a natural or artificial socket to serve as a root or abutment.
- (2) Intra-osseous dental implant - a bone transfixation to obtain a canal traversed by a metal tube serving as a dental support.
- (3) Subperiosteal dental implant - a one-piece casting mesh with four abutments which is placed on the bone, under the periosteum, with the four abutments protruding into the oral cavity, on to which a denture is fixed.

According to Weinman, about 1200 implants have been made in the last ten years. This is not a large number for this length of time. Only Behrman has reported on the use of platinum cobalt alloy as a magnetic implant. Yet no complete histological study has ever been made of the effect of the magnetized alloy upon oral tissues. The following investigation of an alloy containing platinum 76.5% and cobalt 23.5%, and possessing magnetic properties was undertaken to determine the reaction of normal tissues to a magnetic implant. The objective of this investigation is to make available information of tissue reaction in a sequence corresponding to the repair of bone and a mucoperiosteal flap.

Furthermore, the use of such magnetic implants already have been used in the management of full denture prosthesis. This study proposes to make available detailed information useful to understanding tissue reaction as well as the feasibility of magnetic metallic implants in oral prosthetic management.

A careful review of the literature has failed to reveal any work where the problem has been approached from a purely histological point of view, giving added reason for the present study.

B. THE METALS: PLATINUM AND COBALT

PLATINUM - is a chemical element (symbol Pt. atomic number 78, atomic weight 195.23) which is a very heavy precious silver-white

metal. The usefulness of this metal is due to its resistance to corrosion or chemical attack and to its high melting point of $1,773^{\circ}\text{C}$. When brought to a white heat in air, it retains its bright surface. It is scarcely attacked by simple acids, but does dissolve readily in aqua regia (HCl , HNO_3). Platinum has a very high specific gravity of 21.46. Platinum occurs in native alloys which frequently contain smaller amounts of other platinum metals.

COBALT - is a metallic element (symbol CO, atomic number 27, atomic weight 58.94) which when polished is a silver white metal with a bluish cast. The metal was first prepared in an impure state by G. Brandt in 1742. He observed its magnetic properties and high melting point.

PHYSICAL PROPERTIES ARE:

Density	- 8.8 g/ml
Melting Point	- $1,480^{\circ}\text{C}$
Boiling Point	- $2,415^{\circ}\text{C}$
Tensile Strength	- 60,000 lbs. per sq. in.

Cobalt Metal is strongly magnetic (ferromagnetism) at all temperatures up to $1,150^{\circ}\text{C}$. The alloys with iron have magnetic properties and are used to make permanent magnets.

C. MAGNETISM

General Description of Magnetism - The quality of magnetism first apparent to the ancients and us today is the attractive force that exists between a natural magnet (lodestone, a magnetic oxide of iron) or an artificial magnet and a piece of soft iron.

When a magnet is broken new poles appear near the break so that each piece contains the same number of poles of each kind.

MAGNETIC FIELD - a magnet will attract a piece of iron even though the two are not in contact, and this action at a distance is said to be due to the magnetic field, or the field of force around the magnet. This field may be examined by sprinkling iron filings around a magnet, whereupon they form in lines that converge on the poles and indicate also the direction a compass needle would take if placed at any point.

Poles exert forces on each other, north and south poles attract each other and like poles repel with a force that varies inversely as the square of the distance between them.

$$\text{Magnetic Force: } F_o = \frac{1}{D^2} \text{ (cm)}$$

A unit pole is a general term defined so that two unit poles of like kind, one centimeter apart repel each other with a force of one dyne.

The strength of field of force, or the magnetic field strength, or magnetizing force may be defined in terms of magnetic poles: At one centimeter from a unit pole the field strength is one "oersted".

A magnetic field may be produced by a current of electricity, as well as a magnet, and the unit of field strength can also be defined in terms of a current. A magnetic field has direction as well as strength; the direction is that in which a north pole subjected to it, tends to move; or that indicated by a small compass placed within the field. The unit of magnetic field strength is the "oersted".

D. BRIEF DESCRIPTION OF THE MANDIBLE AND THE DENTITION

OF THE DOG

MANDIBLE

The mandible consists of two symmetrical bones joined together in the anterior region by syndesmosis in the form of a V. Each half can be divided into a body, the horizontal part, and a ramus, the vertical part. The body carries the alveolar process and the teeth.

On the lateral surface of the body we find three mental foramina which lie in a horizontal plane midway between the inferior border of the body and the crest of the alveolar process.

In a vertical plane between the first and second incisor is located

the small anterior foramen 2-3 mm from the symphysis. The middle foramen, the largest of the three is located in a vertical plane between the first and second premolar. The posterior foramen is located below the bifurcation of the roots of the third premolar. The canal which opens at each metal foramen is directed inward, downward, and backward.

The ramus carries three processes: (1) the coronoid process (2) the condylar process and (3) the angular process.

On the lateral surface of the body of the ramus is located a rather large ovoid concavity, the masseteric fossa. The anterior border of the masseteric fossa continues upward into the anterior border of the coronoid process. The infraposterior border continues upward and backward toward the lateral border of the condyle. The masseteric fossa reaches to the notch between the coronoid and condylar processes. The anterior border of the ramus does not meet the posterior end of the alveolar process, but continues to it on the lateral surface of the body as a blunt ridge, an oblique ridge which runs downward and forward. This bony elevation is strong and prominent in its central portion, and gradually flattening out and disappearing near the lower border below the second molar.

The coronoid process is a rather flat triangular bony plate

elongated into a small backward curved hook. Its posterior border is concave; its anterior border slightly convex, and continues into the anterior border of the ramus.

The condylar process is divided from the coronoid and angular processes by concave notches. The condylar process consists of a condyle, a circumscribed head and cylindroid in shape, which is attached to the body of the mandibular ramus by the neck.

The angular process, the smallest of the three processes, is a rough hooked eminence located below the condylar process.

THE TEETH

TERMINOLOGY - the formula for the deciduous dentition of the dog is:

$$I \ 3/3, \ C \ 1/1, \ M \ 3/3 = 7/7 \times 2 = 28$$

The formula for the permanent dentition of the dog is:

$$I \ 3/3, \ C \ 1/1, \ Pm \ 4/4, \ M \ 2/3 = \frac{10}{11} \times 2 = 42$$

The teeth are classified from the anterior to posterior as incisors, canines, premolars, and molars. The nomenclature is the same for the incisors and canines of both sets of teeth. In the anterior region each half of the mandible has a first, second, and third incisor. Also referred to as a central incisor, an intermediate incisor, and a corner incisor.

General Description - The incisor teeth are placed close together

and increase in size from the first to the third. The crown of each incisor presents three unequal projections, and on the lingual surface there is a curved ridge, the cingulum, close to the neck.

The canine teeth are larger, with conical curved crowns. A cingulum is present, as it is on all teeth. The upper canine is separated by a gap from the third incisor, and a similar gap separates the lower canine from the first premolar, these gaps receive the opposed tooth when the teeth are brought together. The incisors and canines of both jaws are single rooted teeth.

The premolar teeth increase in size from anterior to posterior. The first premolar is small and has only one root. The second and third premolar in the maxilla, and the second, third, and fourth premolar in the mandible have two roots. The fourth premolar in the maxilla is much larger than the others and has three roots.

The two molar teeth in the maxilla have three roots. The first molar carries two high buccal cusps and the two small lingual cusps. The lingual part of the crown is much lower than the buccal and constitutes the chewing surface of the tooth. The second molar is similar to the first, but much smaller in size.

The first mandibular molar is much larger than its adjacent teeth. Its crown is larger with four cusps similar to that of the fourth premolar.

The anterior portion possesses two high cusps which are divided by a sectorial ridge. The posterior portion, the taloned, carries two small cusps which are much lower and adds a masticatory surface to the tooth. It has a pronounced incisal edge and this interdigitates with the incisal edge of the upper fourth premolar. Thus, the upper fourth premolar and the lower first molar are distinguished by the name of sectorial or carnassial teeth of their respective jaw.

The second and third mandibular molars have tubercular chewing surfaces, and the third is smaller than the second. The first and second mandibular molars have two roots, whereas the last molar has only one.

PLATE I

- Figure 1.** Photograph of a dog's skull showing the relationship between maxillary and mandibular teeth. Note:
- (1) large canine teeth with conical curved crown**
 - (2) how maxillary canine fits into gap between mandibular canine and the first pre molar and how mandibular canine fits into gap between maxillary third incisor and maxillary canine.**

E. Photographs, diagrams, and illustrations of the skull of the dog.

PLATE I

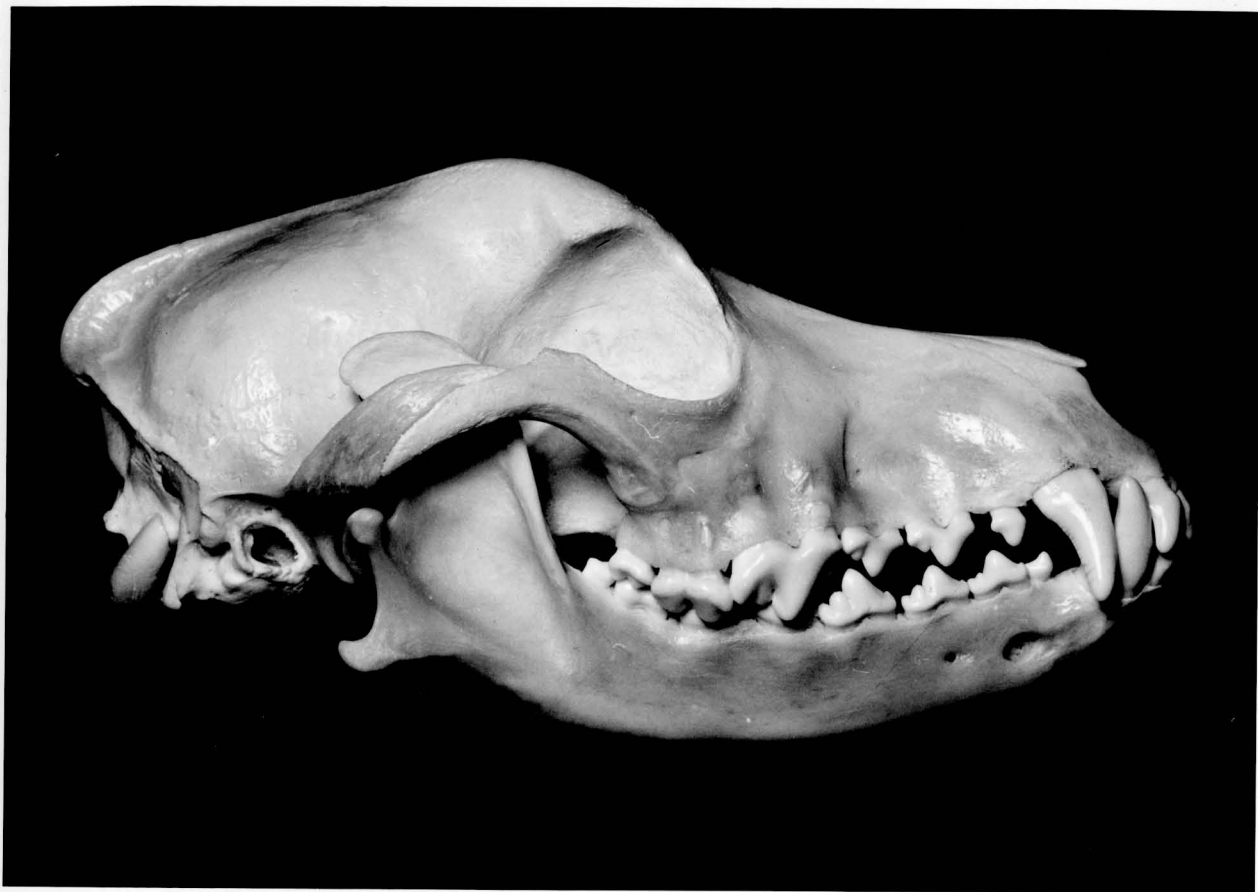


Figure 1

PLATE II

Figure 2. Diagrammatic drawing of the mandible of the dog illustrating anatomical landmarks.

PLATE II

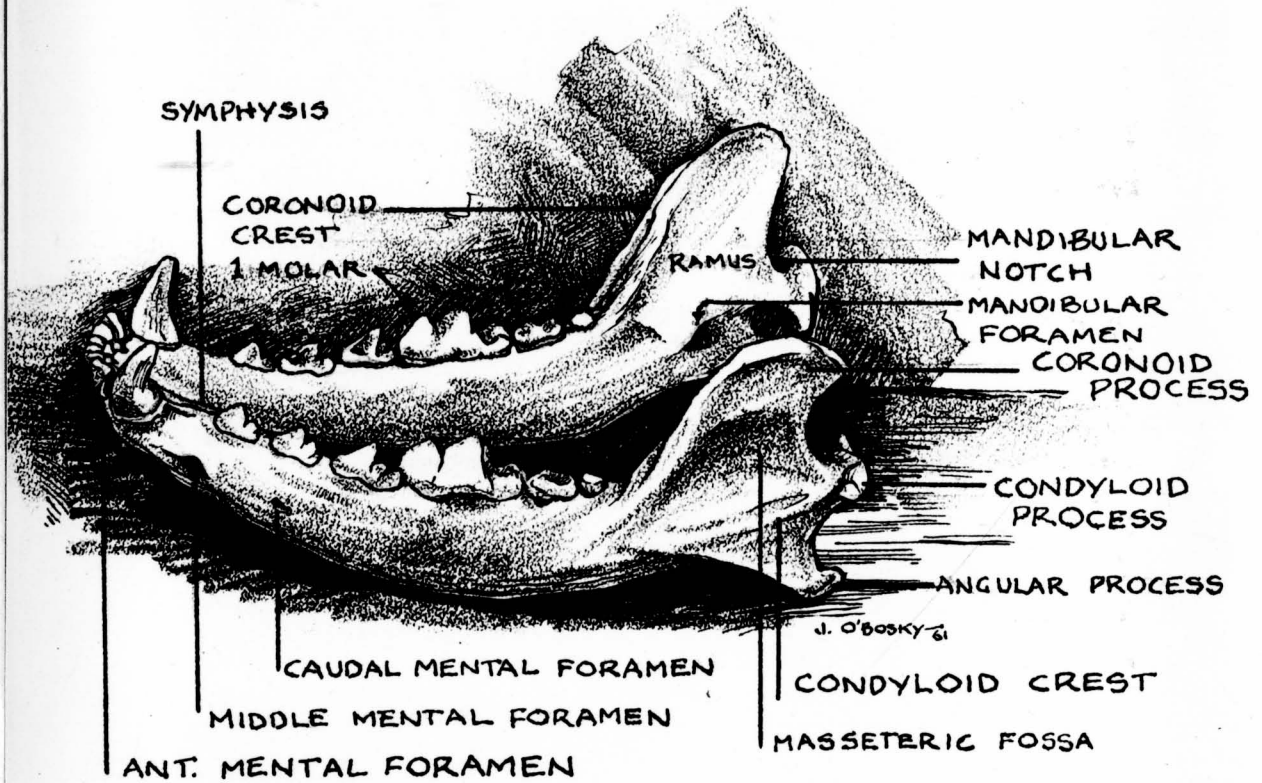


Figure 2

PLATE III

Figure 3. Photograph of mandible of a dog. Note: (1) Mandible consists of two symmetrical bones joined together in the anterior region by syndesmosis in the form of a V. (2) On the lateral surface of the body of the ramus is located a rather large ovoid concavity, the masseteric fossa.

PLATE III



Figure 3

PLATE IV

Figure 4. Photograph of the lateral surface of the body of the mandible of a dog. Note: (1) 3 mental foramina which lie in a horizontal plane midway between the inferior border of the body and the crest of the alveolar process. (2) The middle foramen, the largest of the three is located in a vertical plane between the first and second premolar. Note: (i) The ramus carries three processes: (a) the coronoid process (b) the condylar process and (c) the angular process.

PLATE IV

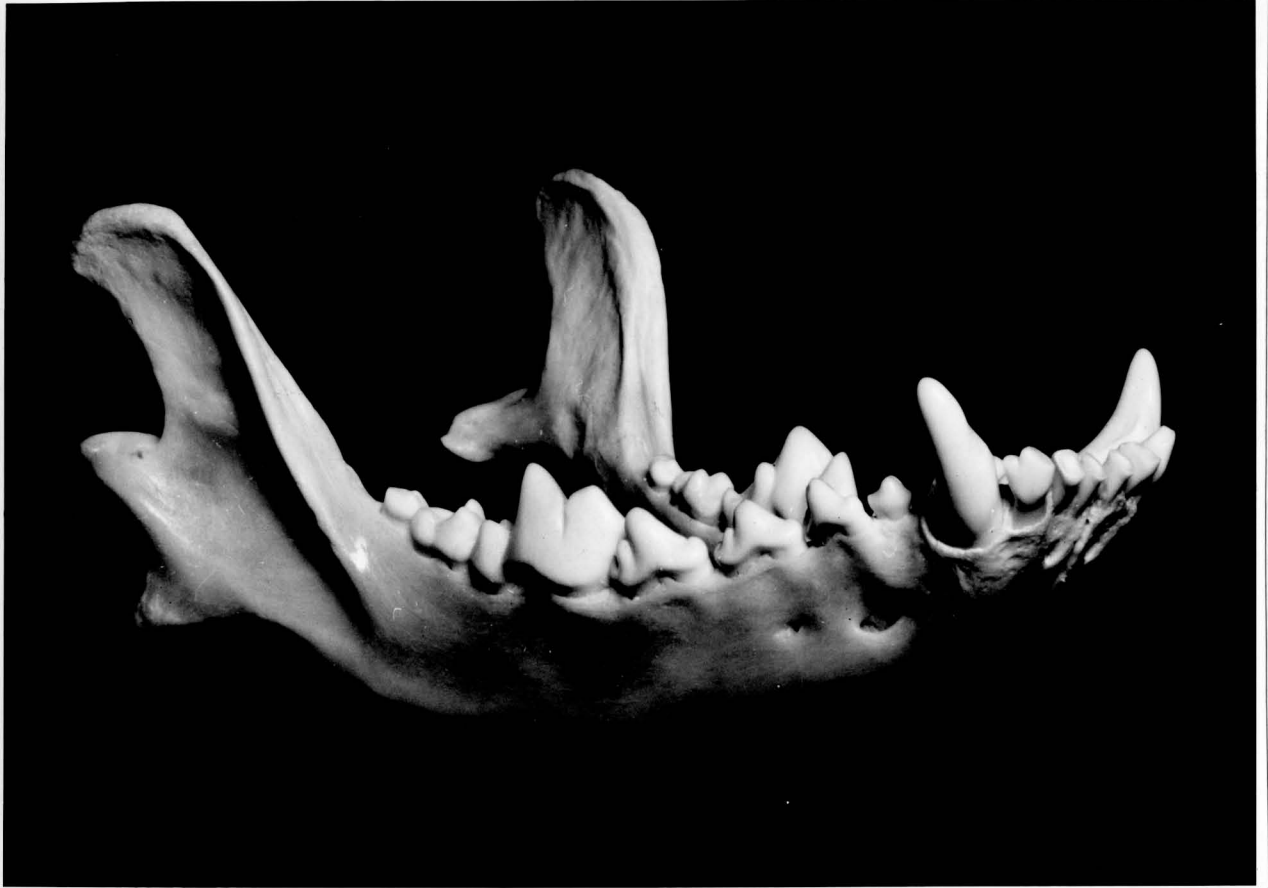


Figure 4

PLATE V

Figure 5. Photograph of partially dissected head of dog illustrating anatomical relationship between the deciduous or temporary teeth and the permanent teeth of a dog. (From Bradley and Grahame: *Topographical Anatomy of the Dog*, Oliver & Boyd, Ltd., Edinburgh Scotland, 1959.)

Figure 6. Diagrammatic drawing of the anatomical position of the permanent teeth of a dog. (From Bradley and Grahame: *Topographical Anatomy of the Dog*, Oliver & Boyd, Ltd., Edinburgh, Scotland, 1959.)

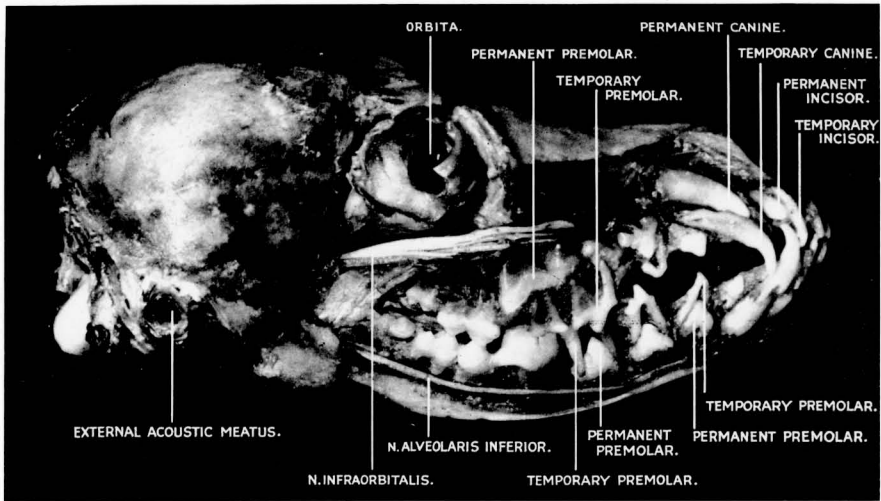


Figure 5

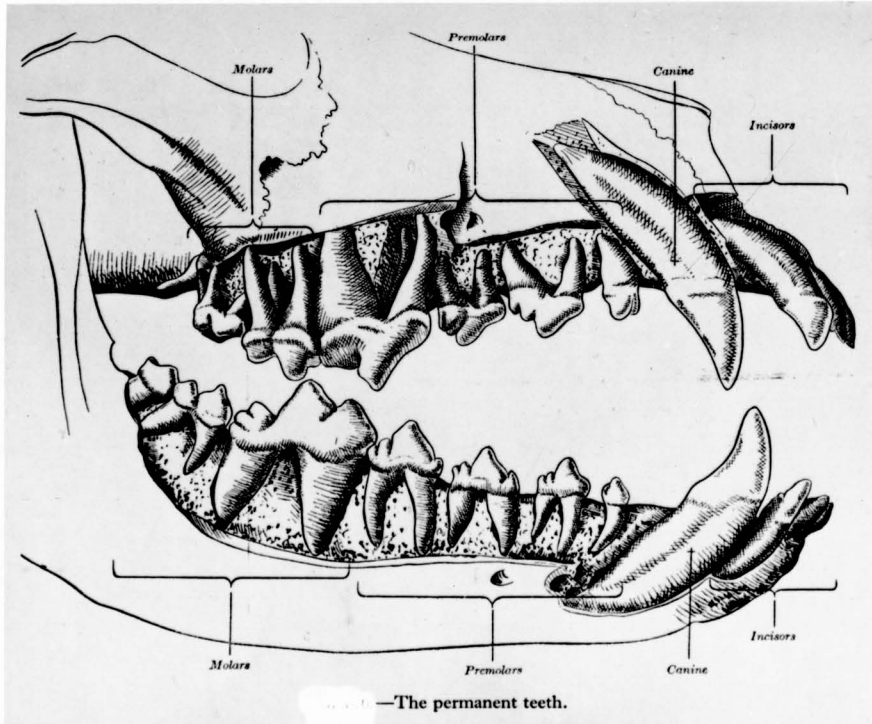


Figure 6

PLATE VI

Figure 7. Photograph of selected skulls, which were bleached in a solution of Albone C (30% H₂O₂). Note similarities.

The animals were sacrificed by means of lethal intraperitoneal dose of sodium pentobarbital. The heads were then severed and the soft tissues dissected. The selected skulls were bleached in a solution of Albone C (30% H₂O₂).

PLATE VI



Figure 7

PLATE VII

Figure 8. Photographs of selected skulls note similarities.

PLATE VII



Figure 8

CHAPTER III

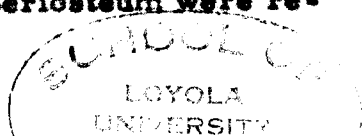
MATERIAL AND METHODS

Ten young adult, apparently normal, mongrel dogs with complete dentitions were selected at random from the general animal medical school supply without regard to sex or breed.

Preoperative procedure was as follows: The animals were premedicated with 1.2×10^6 units of long-acting penicillin (Bicillin, Wyeth). Anesthesia was induced by intraperitoneal injection of sodium pentobarbital (nembutal, Abbot); 1 c. c. of a 5 percent solution per 5 lbs. body weight (approximately 50 mg. per 15 kg body weight). This was supplemented with a mandibular block and local infiltration at the surgical site of approximately 2 to 3 c. c. of 1 percent procaine hydrochloride with epinephrine 1:50,000 solution to aid in hemostasis and to obtund more profoundly sensory nerves to prevent reflexes from arising in the periosteum of the mandible. The animals were in the stage of surgical anesthesia in approximately 15 minutes.

After securing the animals to the operative table, each dog was draped with sterile towels exposing only the operative site. The mucosa and teeth in the mandibular canine, premolar, and molar area was painted with tincture of merthiolate prior to injection and incision.

Under sterile precautions, with a number 15 blade mounted on a Bard Parker scapel, an incision was made through the attached gingiva distal to the canine and extending to the second molar area. A mucoperiosteal flap was prepared, the mucous membrane and periosteum was carefully reflected away from the body of the mandible. Using a steady stream of normal saline solution and with the use of Nos. 701, 557 and 560 carbex fissure burs mounted in a dental hand piece, a bony vault was prepared in the cortex at the inferior border of the mandible, between the lower left fourth premolar and first molar. A sterile magnetic implant magnetized through its diameter composed of platinum-cobalt alloy (platinum 76.5% and cobalt 23.5%) in the shape of a flattened cylinder which is capable to sustaining a load of 100 grams and possess a magnetic force of 3,283 oerstads, measuring $1/4''$ in length, less than $1/8''$ in height and a little more than $1/8''$ in width was used as a template to facilitate the construction of the vault. (Precise dimensions of the implant are: $0.25'' \times 0.14'' \times 0.10''$ or $6.35 \times 3.55 \times 2.54$ mm). The vault was finished with a bone file to remove any overhang or bony spicules, then debrided with a spoon excavator and flushed with normal saline solution. The implant was then placed in the vault, using an orangewood stick for instrumentation, it was positioned carefully, so that it was flush or slightly below the margins of the vault. The mucosa and periosteum were re-



approximated to their normal position to cover the implant and sutured to place using several interrupted 000 (triple 0) silk sutures. Pressure against the implant was made repeatedly with the orangewood stick to be sure it is retained in the vault.

A variation in the surgical procedure was made beginning with the third dog. The flap design was modified somewhat. Instead of reflecting the gingiva from the crest of the alveolar process downward; the incision was made in the buccal sulcus and the gingiva was reflected upward toward the crest of the alveolar process.

In establishing a control four non-magnetic platinum-cobalt alloy (platinum 76.5% and cobalt 23.5%) implants of corresponding size and a comparable area of the apposite mandibular body was used. An aseptic technique was observed throughout the surgical procedure.

Postoperatively, the diet consisted of milk day of surgery after which the animals were maintained on Purina dog kibbled meal, one part; Miller's puppy meal, two parts; and freshly ground horse meat, one part. The dogs were kept under strict supervision and were permitted the freedom of the kennels.

By means of a lethal dose, 15 cc. of a 5% solution of sodium pentobarbital the animals were sacrificed at intervals of twenty-four hours; forty-eight hours; seventy-two hours; nine days eight hours; one month,

one month two weeks, two months, three months, and six months. At these designated intervals, the mandibles were removed surgically by means of a gigli saw. At the time the dogs were sacrificed the macroscopic changes in tissues were noted and photographed in color. Roentgenologic examination of the mandible was made. The Radiographic exposure time was one second for the periapical film and one and one-half seconds for the occlusal films at 10 M. A. and 65 K. V. P.

Using a steady stream of normal saline solution a wide segment containing the implant was resected. The specimens were fixed in 10% formalin for 4 hours and the formalin freshly replaced to continue fixation for 24 hours. They were then decalcified in formic acid sodium citrate solution, embedded in cellodin and cut at eight to ten microns. The sections were stained by hemotoxylin and eosin, and used for histologic study.

CHAPTER IV

FINDINGS

Dog No. 1 Twenty-Four Hour Specimen-Magnetic Implant

Operation - June 27, 1960

Sacrificed - June 28, 1960

Description of dog:

1. Hair - Long
2. Sex - female
3. Color - brown and white
4. Breed - mongrel
5. Weight - preoperative - 19 lbs.
6. Approximate age - 1 1/2 years

A. MACROSCOPIC FINDINGS

1. Weight - postoperative 18 lbs.
2. Gross Changes - there is a slight oozing of a hemorrhagic or "jelly-like" exudate along the line of incision where the blood clot does not glue together the cut gingival tissue. Several sutures are seen, some have been dislodged, and some are missing. The oral mucosa and periosteum are partially separated from the body of the

mandible. The margins of the gingival tissue along the surgical site is red, rolled and elevated. The oral mucosa not disturbed by surgery is characterized by a glistening surface and is pink-gray in color. There is no discoloration of tissue in the site of the metallic implant.

Between the two approximated gingival tissues and the proximal areas of the teeth are seen a few scattered dog hairs and food debris.

3. Metal - The metal remained unchanged; shows no discoloration, is non-corroded, and is smooth and shiny.

B. HISTOLOGIC FINDINGS

Epithelium: - The epithelial component of the mucosa covering the magnetic implant is missing.

Submucosa: - The connective tissue remaining consists of a fibrous connective tissue, muscle, and contains mucous glands. The submucosa with the periosteum is completely separated from the body of the mandible. The collagenous fibers in the connective tissue of the flap are separated by edema and polymorphonuclear leukocytes infiltration. On the inner surface of the mucoperiosteal flap is attached a fibrin clot.

Bone: - The defect in the lateral surface of the mandibular body extends through the cortex, the marrow, and into and involving the mandibular canal and its content; the mandibular nerve, artery, and

vein. The walls of the cortical plate of bone on the lateral surface are sharply cut away. The cortical plate itself is rather dense and fairly smooth. The margins of the cut bone surrounding the implant show the lacunae of the osteocytes still contain in them remnants of the osteocyte itself, and some contraction of the tissue of the Haversian system. The marrow is characterized by delicate loose connective tissue, adipose tissue, and capillaries.

The Blood Clot: - The blood clot which completely surrounds the empty space previously occupied by the metallic implant extends from the inner surface of the mucoperiosteal flap into the defect and continues into the mandibular canal and becomes continuous with the loose connective tissue of the bone marrow.

The clot is composed of a very delicate irregular arranged network of fibrin. The spaces between the fibrinous threads are occupied by erythrocytes, a few inflammatory cells most of which are polymorphonuclear leukocytes, and a few minute spicules of bone that have remained in the site following surgery.

Dog No. 2 Forty-Eight Hour Specimen - Magnetic Implant

Operation - July 29, 1960

Died - July 31, 1960. Autopsy performed;

microscopic section of lung revealed cause of

death to be pneumonia; heart, liver, and kidney were normal.

Description of dog:

1. Hair - long
2. Sex - female
3. Color - black and brown
4. Breed - mongrel
5. Weight - preoperative - 20 lbs.
6. Approximate age - 2 years

A. MACROSCOPIC FINDINGS:

1. Weight - postoperative 18 lbs.
2. Gross Changes - There is a mild generalized swelling of the left jaw. There are remnants of a blood clot along the line of incision which glues together parts of the cut gingival tissue. Several sutures are still in place, while others are dislodged and some are missing. The oral mucosa and periosteum are partially separated from the body of the mandible. The margins of the gingival tissue along the surgical site are fiery red, somewhat rolled and elevated. The oral mucosa directly overlying the implant is somewhat elevated. There is no discoloration of tissue in the site of the metallic implant.

Between the two approximated gingival tissues and the proximal areas of the teeth are seen a few scattered dog hairs and food debris.

3. Metal - The metal remained unchanged; shows no discoloration; is non-corroded, and is smooth and shiny.

B. HISTOLOGIC FINDINGS

Epithelium: - The epithelial component of the mucosa covering the magnetic implant is missing.

Submucosa: - The flap part that over-lies the empty space formerly occupied by the metallic implant consists of essentially fibrous connective tissue; the collagenous fibers are separated by edema. Many polymorphonuclear leukocytes and blood pigment are seen throughout the flap. The inner surface of the flap is attached to the fibrin clot. The submucosa of the alveolar mucosa and the periosteum are separated from the body of the mandible.

Bone: - The cortical plate of bone on the lateral surface of the mandible is sharply cut away. The cut surface of bone extends into the mandibular canal, but not disturbing the mandibular nerve, artery, or vein. There is evidence of contraction of the tissues of the Haversian canal adjacent to the cut surface of the bone nearest the implant. The lacunae nearest the marginal surface of the cut

bone are empty. The marrow is composed of a delicate loose connective tissue, adipose tissue and capillaries.

The Blood Clot: - The clot extends from the buccal surface of the cortical plate of bone into the mandibular canal and becomes continuous with the loose connective tissue of the bone marrow, and completely surrounds the implant. The amount of clot has been reduced in size.

Along the margins of the clot there are many polymorphonuclear leukocytes. Within the clot is a delicate meshwork of fibrin, red blood cells, polymorphonuclear leukocytes, and a few scattered minute spicules of bone.

Dog No. 3 - Seventy-Two Hour Specimen - Magnetic Implant

Operation - July 28, 1960

Sacrificed - July 31, 1960

Description of dog:

1. Hair - long
2. Sex - male
3. Color - black and brown
4. Breed - mongrel
5. Weight - preoperative - 25 lbs.
6. Approximate age - 2 1/2 years

A. MACROSCOPIC FINDINGS:

1. Weight - postoperative - 23 lbs.
2. Gross Changes - The left cheek at the inferior border of jaw is slightly swollen. The line of incision is clearly seen with a few sutures in place. Some of the sutures have become loosened and some are missing. The oral mucosa and periosteum are fairly well approximated along the body of the mandible. Very little of the blood clot remains. The gingival tissue directly above the implant and along the surgical site is red and slightly swollen. There is no discoloration of tissue in the site of the metallic implant.
3. Metal - The metal remained unchanged; shows no discoloration, is non-corroded, and is smooth and shiny.

B. HISTOLOGIC FINDINGS:

Epithelium: - The epithelial component of the mucosa covering the magnetic implant is missing.

Submucosa: - The connective tissue remaining consists of a

- fibrous connective tissue, muscle, and contains mucous glands.

The submucosa with the periosteum is separated from the body of the mandible.

The fibrous connective tissue is separated and in between the fibers are many polymorphonuclear leukocytes. On the very inner

surface of the flap is attached a fibrin clot with polymorphonuclear leukocytes.

Bone: - The cortical plate of bone is sharply cut away and extends beyond the marrow and into the mandibular canal. The tissues of the Haversian canal shows evidence of necrosis. There is proliferation of reserve or undifferentiated cells within the loose connective tissue of the marrow. Many new capillaries are seen in the marrow spaces.

Osteoclasts are present on the outer cut surface of the cortical and cancellous bone, and osteoblasts are seen on the inner surface of the cancellous bone trabeculae.

The Blood Clot: - The fibrin clot completely surrounds the empty space previously occupied by the metallic implant. The clot extends from the inner surface of the mucoperiosteal flap into the defect, and continues into the mandibular canal. On the cut surfaces of the bone, the clot becomes continuous with the loose connective tissue of the bone marrow.

In the clot portion which is attached to the loose connective tissue of the marrow there is evidence of new capillaries and many undifferentiated cells.

The clot itself is made up of a very delicate meshwork of fibers,

erythrocytes, polymorphonuclear leukocytes, some dark staining hemosiderin granules, and a few minute spicules of bone.

Deep to the cut surface in the marrow there are darkly stained granules of hemosiderin within the cytoplasm of macrophages.

Spindle or cigar shape reserve cells are present in the fibrous meshwork of the clot.

Dog No. 4 - Nine Days Eight Hour Specimen - Magnetic Implant

Operation - June 21, 1960

Sacrificed - June 30, 1960. Animal stopped eating on eighth day; thus sacrificed at nine days eight hours.

Autopsy performed, microscopic section of lung was consistent with clinical impression of pneumonia; heart, liver, and kidney were normal.

Description of dog:

1. Hair - short
2. Sex - female
3. Color - brown
4. Breed - mongrel
5. Weight - preoperative - 17 lbs.
6. Approximate age - 2 years

A. MACROSCOPIC FINDINGS:

1. Weight - Postoperative - 15 lbs.
2. Gross Changes - The line of incision is indicative by a rather shallow depressed groove which links the previously incised edges. There are a few sutures in place. The oral mucosa is loosely attached to the body of the mandible. The gingiva, rose-pink in color, is smooth and glistening. There is no discoloration of tissue in the site of the metallic implant.
3. Metal - The metal remained unchanged; shows no discoloration, is non-corroded, and is smooth and shiny.

B. HISTOLOGIC FINDINGS:

Epithelium: - The epithelial component of the mucosa covering the magnetic implant is missing.

Submucosa: - The connective tissue remaining consists of a fibrous connective tissue, muscle, and contains mucous glands. The submucosa with the periosteum is only slightly separated from the body of the mandible.

On the inner surface of the mucoperiosteal flap which is continuous with the clot there are seen fibroblasts and collagenous fibers, few red blood cells, few polymorphonuclear leukocytes and many undifferentiated or reserve connective tissue cells.

The connective tissue immediately in contact with the implant shows

more young fibroblasts with elongated nuclei and collagenous fibers between them, in addition to some hemorrhage and blood pigment. This is the first time the connective tissue immediately adjacent to the implant shows definite evidence of fibroblastic activity. Fewer inflammatory cells are recognized at this time.

Bone: - The cortical plate of bone is sharply cut away. The defect extends through the marrow and on into the mandibular canal, exposing the mandibular nerve, artery, and vein. Osteoclasts are found on the cut surface of bone while on the inner surface of cancellous bone osteoblasts opposing new bone. On the outer margins of the empty space previously occupied by the implant are seen young fibroblasts with collagenous fibers between them.

The Blood Clot: - The clot extends from the inner surface of the flap into the mandibular canal and is continuous with the loose connective tissue of the bone marrow completely surrounding the implant site.

The clot which is in continuity with the cut bone shows continual organization by the proliferation and infiltration of many stellate shape cells (fibroblasts).

Within the clot there are many undifferentiated or reserve cells, some of which are stellate in shape. Other cells are elongated in

shape with collagenous fibers in between them, these are the fibroblasts. Also present within the clot are red blood cells, a few polymorphonuclear leukocytes, blood pigment, capillaries and some minute spicules of bone.

The clot shows definite evidence of organization at this time. The red blood cells shows continued hemolysis as there is hemosiderin pigment around the margins of the implant, and under high power this pigment is actually within histiocytes as phagocytized particles.

There is almost complete absence of the polymorphonuclear leukocytes as compared to the earlier specimens.

Dog No. 5 - Two Week Specimen - Magnetic Implant

Operation - June 28, 1960

Sacrificed - July 12, 1960

Description of dog:

1. Hair - short
2. Sex - male
3. Color - black and white
4. Breed - mongrel
5. Weight - preoperative 20 lbs.
6. Approximate age - 3 years

A. MACROSCOPIC FINDINGS:

1. Weight - Postoperative - 17 lbs.
2. Gross Changes - The line of incision is indicated by a shallow depressed groove which links the previously incised edges. One suture remains over the line of incision between the proximal surface of the lower left fourth premolar and the first molar. The oral mucosa is rather firmly attached to the body of the mandible. The gingiva, pink in color, is smooth with a glistening appearance.
3. Metal - The metal remained unchanged; shows no discoloration; is non-corroded, and is smooth and shiny.

B. HISTOLOGIC FINDINGS:

Epithelium: - The epithelial component of the mucosa covering the implant is absent.

Submucosa: - The connective tissue remaining consists of a fibrous connective tissue, muscle, and contains mucous glands.

The periosteum is attached to the body of the mandible.

The flap appears almost normal as the edema has been reduced considerably, and now consists of dense fibrous connective tissue, with only a few residual polymorphonuclear leukocytes which show evidence of necrosis.

Bone: - There is vigorous bone apposition in the cancellous bone as many osteoblasts are seen. Also, bone apposition is seen on the

walls of the cortical plate which had been previously cut away.

The Fibrin Clot: - The fibrin material of the former blood clot now is completely replaced by fibrous connective tissue which is continuous from the inner surface of the flap to the connective tissue of the bone marrow and into the mandibular canal completely surrounding the empty space previously occupied by the implant

Between the fibers are seen a few necrotic polymorphonuclear leukocytes; hemolyzed red blood cells, and hemosiderin pigment within histocytes. There are osteoblasts and osteoclasts present on the small fragments of bone.

Dog No. 6 - One Month Specimen - Magnetic Implant

Operation - July 1, 1960

Sacrificed - July 30, 1960

Description of dog:

1. Hair - long
2. Sex - female
3. Color - black and brown
4. Breed - mongrel
5. Weight - preoperative - 20 lbs.
6. Approximate age - 2 years

A. MACROSCOPIC FINDINGS:

1. Weight - Postoperative - 15 lbs.

2. Gross Changes - There is no evidence of incision or surgery.

The entire wound is covered by a continuous smooth, glistening gingival epithelium which is pink-gray in color. There is no contrast of color between the tissues. The oral mucosa is firmly attached to the body of the mandible.

3. Metal - The metal remained unchanged; shows no discoloration; is non-corroded, and is smooth and shiny.

B. HISTOLOGIC FINDINGS:

Epithelium: - The epithelial component of the mucosa covering the implant is absent.

Submucosa: - The connective tissue remaining consists of a fibrous connective tissue, muscle, and contains mucous glands. The mucoperiosteal flap is in immediate contact with the bone surface. The periosteum itself has completely re-attached to the bone, and a few osteoblasts are present.

The inner surface of the flap is in direct communication with a less condense fibrous connective tissue which is in contact with the empty space.

Bone: - The walls of the cortical plate which had been cut shows

reversal lines where new bone has been formed creating sharp line of demarcation between the old and the new bone. There is very little osteoclastic activity, and reduced osteoblastic activity as compared with two week sections. The marrow space is quite vascular, with an increased amount of fibrosis present extending into and surrounding some of the cancellous bone. Deep to the implant directly below the mandibular canal there is evidence of new bone formation. So that actually, the diameter of the mandibular canal has been reduced by this new bone formation.

The space formerly occupied by the magnetic implant is completely lined by a mature, dense fibrous connective tissue capsule. This fibrous connective tissue capsule lines the inner surface of the mucoperiosteal flap and continues with the periosteum, then extends deep into the marrow space covering the previously cut surface of the defect, thus completely encapsulating the implant.

There is no evidence remaining of the fibrin clot. The young proliferated connective tissue which was seen at 72 hours, and at 9 days 8 hours has all been resolved in the form of a fibrous connective tissue capsule. All the inflammatory cells are gone.

The major portion of the blood pigment has been removed. Under high power some remnants of blood pigment is seen within histio-

cytes.

Young connective tissue is seen only immediately adjacent to the bone in which bone apposition and bone resorption is active.

Most of the marrow space as was seen in the two week specimen is quite vascular and shows some evidence of fibrosis, otherwise it is normal.

The Fibrous Capsule: - In a small localized area within the capsule are seen a few inflammatory cells, most of which show evidence of necrosis. Other than this small localized area the fibrous capsule is free of any inflammation.

Dog No. 7 - One Month Two Week Specimen - Magnetic Implant

Operation - September 1, 1960

Died - October 14, 1960. Autopsy performed; microscopic section of lung revealed cause of death to be pneumonia; heart, liver, and kidney were normal.

Description of dog:

1. Hair - short
2. Sex - male
3. Color - brown
4. Breed - mongrel
5. Weight - preoperative - 24 lbs.

6. Approximate age - 2 1/2 years

A. MACROSCOPIC FINDINGS:

1. Weight - postoperative - 20 lbs.

2. Gross changes - There is no evidence of incision or surgery.

The entire wound is covered by a continuous smooth, glistening gingival epithelium which is pink-gray in color. There is no contrast of color between the tissues. The oral mucosa is firmly attached to the body of the mandible.

3. Metal - The metal remained unchanged; shows no discoloration; is non-corroded, and is smooth and shiny.

B. HISTOLOGIC FINDINGS:

Epithelium: - The epithelial component of the mucosa covering the implant is absent.

Submucosa: - The mucoperiosteal flap is in immediate contact with the bone surface. The periosteum is firmly attached to the bone. The inner surface of the flap is attached firmly to a dense fibrous connective tissue which surrounds the empty space created for the metallic implant.

Bone: - There is very little evidence of any further bone resorption or bone apposition except that resorption had occurred by reversal lines and apposition has occurred replacing this bone loss within

the marrow as well as the cut surface of the bone cortex by a sharp line of demarcation between the old and new bone.

Most of the marrow space as was mentioned in the one month specimen is quite vascular and shows some evidence of fibrosis. The cancellous bone is normal except where it shows reversal lines, which is also normal now.

There is an increase in the fibrosis of the marrow immediately around the capsule.

The Fibrous Capsule: - The empty space or defect created for the implant is lined by a mature dense fibrous connective tissue capsule which completely encapsulates the implant. This fibrous capsule intervenes between the cortical bone of the buccal plate and the implant and extends out to the periosteum and communicates directly with the inner surface of the mucoperiosteal flap. The fibrous capsule further extends from the periosteum to the opposite cortical bone defect and runs deep into the marrow space completely surrounding the implant. Thus, the implant is encapsulated in a dense fibrous capsule which in turn is bound to bone and to the overlying mucoperiosteum.

In a small localized area within the capsule are seen a few inflammatory cells, most of which show evidence of necrosis or degenera-

tion. On the inner surface of the capsule are seen some free cells which are definite polymorphonuclear leukocytes. Other than this small localized area the fibrous capsule is free of inflammation.

Dog No. 8 - Two Month Specimen - Magnetic Implant

Operation - July 22, 1960

Sacrificed - September 23, 1960

Description of dog:

1. Hair - long
2. Sex - female
3. Color - black
4. Breed- mongrel
5. Weight - preoperative - 30 lbs.
6. Approximate age - 2 years

A. MACROSCOPIC FINDINGS:

1. Weight - postoperative - 25 lbs.
2. Gross changes - There is no evidence of incision or surgery.

The previous wound is covered by a continuous smooth, glistening gingival epithelium which is pink-gray in color. There is no contrast of color between the tissues. The oral mucosa is firmly attached to the body of the mandible.

3. Metal - The metal remained unchanged; shows no discoloration;

is non-corroded, and is smooth and shiny.

B. HISTOLOGIC FINDINGS:

Epithelium: - The epithelial component of the mucosa covering the implant is absent.

Submucosa: - The connective tissue overlying the implant is normal, and consists of a fibrous connective tissue, muscle, and contains mucous glands. The periosteum along the body of the mandible is firmly attached.

The inner surface of the mucoperiosteal flap is attached firmly to a dense fibrous connective tissue sheath which surrounds the empty space created for the metallic implant. There is no evidence of inflammation.

Bone: - A fibrous capsule or sheath lines the lateral cortical plate which bounds the original defect created for the metallic implant. The capsule communicates with the connective tissue surface of the flap.

Deep to the implant a new bony bridge has been apposed and now separates the implant completely from the mandibular canal. The mandibular nerve, artery and vein look normal. On the bony surface nearest the empty space there is some osteoclastic activity, and the cancellous surface of the bony bridge shows

osteoblastic activity.

There is some fibrosis in the marrow spaces, some of which extends into the mandibular canal. The bony walls show reversal lines and continued apposition of new bone. At two months there is now a definite base or bridge of bone upon which lies the fibrous capsule which is in immediate contact with the implant.

The Fibrous Capsule: - The empty space which was previously occupied by the metallic implant and as seen in one month is still completely surrounded by a fibrous capsule. The fibrous capsule forms the inner wall of the flap and lines the buccal cortical plate where the original defect was made. The connective tissue adjacent to the bone is cellular and vascular.

Unlike one month, there is complete lack of inflammatory cells. On the surface of the capsule which lies in direct contact with the new formed bone a few osteoclasts and osteoblasts are seen.

Dog No. 9 - Three Month Specimen - Magnetic Implant

Operation - July 23, 1960

Sacrificed - October 22, 1960

Description of dog:

1. Hair - short

2. Sex - female

3. Color - brown
4. Breed - mongrel
5. Weight - preoperative 22 lbs.
6. Approximate age 2 1/2 years

A. MACROSCOPIC FINDINGS:

1. Weight - postoperative - 10 lbs.
2. Gross Changes - There is no evidence of incision or surgery. The previous wound is covered by a continuous smooth, glistening gingival epithelium which is pink-gray in color. There is no contrast of color between the tissues. It is rather difficult to distinguish the surgical site from the adjacent tissue. The oral mucosa is firmly attached to the body of the mandible.
3. Metal - The metal remained unchanged; shows no discoloration; is non-corroded, and is smooth and shiny.

B. HISTOLOGIC FINDINGS:

Epithelium: - The epithelial component of the mucosa covering the implant is absent.

Submucosa: - The connective tissue underlying the epithelium consists of a fibrous connective tissue, muscle, and contains mucous glands. The mucoperiosteal flap is in immediate contact with bone, as the periosteum has completely re-attached itself to the lateral

surface of the mandible. The inner surface of the mucoperiosteal flap appears normal. There is no cellular reaction of any type seen.

Bone: - The periosteum which is attached to the cut bone on the lateral surface nearest the implant is rounded off and shows a thickening. A few osteoblasts are seen on the adjacent bony surface.

The cut surface of the bony cortex shows resorption or reversal lines on which new bone has been apposed. Upon the newly apposed bone there is a dense fibrous periosteum which covers the cut surface. The actual diameter of the mandibular canal appears to be slightly reduced by this bridge of newly apposed bone. The mandibular nerve, artery and vein are apparently normal. This bony bridge which was also observed at two months shows on its inner surface recent bone apposition. The surface of the bony bridge which lies directly beneath the capsule shows Howship's lacunae. There is some localized remodeling resorption going on in this new bone. The bone which is in immediate contact with the cut surface has been there for some time.

Dog No. 10. - Six Month Specimen - Magnetic Implant

Operation - June 24, 1960

Sacrificed - December 22, 1960

Description of dog:

1. Hair - long
2. Sex - female
3. Color - brown
4. Breed - mongrel
5. Weight - preoperative - 19 lbs.
6. Approximate age - 3 years

A. MACROSCOPIC FINDINGS:

1. Weight - Postoperative - 16 lbs.
2. Gross Changes - There is no evidence of incision or surgery.

The previous wound is covered by a continuous smooth glistening gingival epithelium which is pink-gray in color. There is no contrast of color between the tissues. It is impossible to distinguish the surgical site from the adjacent tissue. The oral mucosa is firmly attached to the body of the mandible.

3. Metal - The metal remained unchanged; shows no discoloration; is non-corroded, and is smooth and shiny.

B. HISTOLOGIC FINDINGS:

Epithelium: - The epithelial component of the mucosa covering the implant is absent.

Submucosa: - The connective tissue underlying the epithelium con-

sists of a fibrous connective tissue, muscle, and contains mucous glands. The mucoperiosteal flap is in immediate contact with bone, as the periosteum is firmly attached to the lateral surface of the mandible. The inner surface of the mucoperiosteal flap directly over the defect is continuous with a fibrous connective tissue.

Bone: - The periosteum which is attached to the cut bone on the lateral surface nearest the implant is rounded off and shows a thickening. A few osteoblasts are seen on the adjacent bony surface.

The cut surface of the cortical plate of bone into which the implant site was made shows complete repair. It is characterized by a reversal line, indicating that resorption had occurred and that apposition had followed a reparative process. Upon the newly apposed bone there is a dense fibrous periosteum which covers the cut surface.

Intervening between the mucoperiosteal flap and the metallic implant is a dense fibrous connective tissue capsule characterized by dense collagenous fibers.

The actual diameter of the mandibular canal appears to be slightly reduced by a bridge of newly apposed bone which separates the mandibular canal from the dense fibrous connective tissue capsule.

The surface of the bony bridge which lies directly beneath the capsule shows Howship's lacunae. There is some localized remodeling resorption going on in this new bone.

In summary, at 6 months, the mucoperiosteal flap is completely restored to normalcy, the bony defect is completely healed and is lined by a dense fibrous connective tissue capsule which encapsulates the empty space previously occupied by the metallic implant. There is complete adaptation of the implant by the formation of a dense fibrous capsule serving as the fibrous periosteum for the cut surface of bone and as a fibrous capsule encapsulating a metallic implant. There is complete absence of foreign body giant cells or inflammatory cells.

CONTROLS

Dog No. 2 - Forty-Eight Hour Specimen - Non Magnetic Implant

Operation - July 29, 1960

Died - July 31, 1960. Autopsy performed; microscopic section of lung revealed cause of death to be pneumonia; heart, liver, kidney were normal.

Description of dog:

1. Hair - long
2. Sex - female

3. Color - black and brown
4. Breed - mongrel
5. Weight - preoperative - 20 lbs.
6. Approximate age - 2 years.

A. MACROSCOPIC FINDINGS:

1. Weight - Postoperative - 18 lbs.
2. Gross Changes - There is a mild generalized swelling of the right jaw. There are remnants of a blood clot along the line of incision which glues together parts of the cut gingival tissue. Several sutures are still in place, while others are dislodged and some are missing. The oral mucosa and periosteum are partially separated from the body of the mandible. The margins of the gingival tissue along the surgical site are fiery red, somewhat rolled and elevated. The oral mucosa directly overlying the implant is somewhat elevated. There is no discoloration of tissue in the adjacent area of the metallic implant.

Between the two approximated gingival tissues and the proximal areas of the teeth are seen a few scattered dog hairs and food debris.
3. Metal - The metal remained unchanged; shows no discoloration; is non-corroded, and is smooth and shiny.

B. HISTOLOGIC FINDINGS:

Epithelium: - The epithelial component of the mucosa covering the implant is absent.

Submucosa: - The portion of the mucoperiosteal flap that overlies the empty space previously occupied by the metallic implant consists of essentially fibrous connective tissue, and collagenous fibers which are separated by an inflammatory zone of infiltration of polymorphonuclear leukocytes, blood pigment and edema. The inner surface of the surgical flap shows some evidence of a fibrin clot.

Bone: - The lateral cortical plate of bone is cut away fairly sharp, some areas are a little roughened. The defect extends into the mandibular canal involving its content the mandibular artery, nerve, and vein. The marrow spaces of the bone cortex shows some distortion of tissue. Most of the lacunae nearest the marginal surface of the cut bone are empty. The marrow is composed of a delicate loose connective tissue, adipose tissue and capillaries.

The Blood Clot: - The clot seen at forty-eight hours is much more reduced in size as compared to twenty-four hour specimen of the magnetic implant site. The clot extends from the inner most surface of the mucoperiosteal flap attaches itself to the cortical plate of bone and dips into the mandibular canal and becomes

continuous with the loose connective tissue of the bone marrow. This fibrin clot completely surrounds or encapsulates the empty space previously occupied by the metallic implant. Along the margins of the clot there are many polymorphonuclear leukocytes. The clot consists of a very delicate irregularly arranged meshwork of fibrin. Within the clot are seen red blood cells, polymorphonuclear, and a few scattered minute spicules of bone which could not be flushed out during surgery.

Dog No. 6 - One Month Specimen - Non Magnetic Implant

Operation - July 1, 1960

Sacrificed - July 30, 1960

Description of dog:

1. Hair - long
2. Sex - female
3. Color - black and brown
4. Breed - mongrel
5. Weight - preoperative - 20 lbs.
6. Approximate age - 2 years

A. MACROSCOPIC FINDINGS:

1. Weight - Postoperative - 15 lbs.
2. Gross Changes - There is no evidence of incision or surgery.

The entire wound is covered by a continuous smooth, glistening gingival epithelium which is pink-gray in color. There is no contrast of color between the tissues. The oral mucosa is firmly attached to the body of the mandible. The surface texture of the gingiva, in comparison with the magnetic implant site, reveals that they are similar.

3. Metal - The metal remained unchanged; shows no discoloration; is non-corroded and is smooth and shiny.

B. HISTOLOGIC FINDINGS:

Epithelium: - The epithelial component of the mucosa covering the implant is absent.

Submucosa: - The connective tissue remaining, consists of a fibrous connective tissue, muscle, and contains mucous glands. The mucoperiosteal flap is in immediate contact with the bone surface. The periosteum has re-attached itself to the bone, and there are a few osteoblasts present.

The inner surface of the mucoperiosteal flap which lies directly over the implant site communicates with a lesser condense fibrous connective tissue sheath which is in immediate contact with the empty space previously occupied by the metallic implant.

Bone: - The walls of the cortical plate which had been cut shows

reversal line where new bone has been formed. The cut surfaces of the bone are scalloped and fragment in appearance. There is very little osteoclastic and osteoblastic activity as compared to earlier specimens seen with the magnetic implant. The marrow space is quite vascular with some fibrosis present which extends into and surrounds some of the cancellous bone. New bone formation is seen directly below the mandibular canal, giving the appearance of a reduction in the size of the canal.

The space formerly occupied by the metallic implant is completely lined by a mature, dense fibrous connective tissue capsule. This capsule or sheath lines the inner surface of the mucoperiosteal flap and becomes continuous with the periosteum, then extends deep into the marrow space covering the previously cut surfaces of the defect; thus, completely encapsulating the implant.

There is no evidence of a fibrin clot or the presence of any inflammatory cells. Under high power some remnants of blood pigment (hemosiderin) is seen within histiocytes. Young connective tissue is seen only immediately adjacent to the bone in which bone apposition and bone resorption is active.

Most of the marrow space is quite vascular and shows some evidence of fibrosis, otherwise, it is normal.

Dog No. 9 - Three Month Specimen - Non Magnetic Implant

Operation - July 23, 1960

Sacrificed - October 22, 1960

Description of dog:

1. Hair - short
2. Sex - female
3. Color - brown
4. Breed - mongrel
5. Weight - preoperative - 22 lbs.
6. Approximate age - 2 1/2 years

A. MACROSCOPIC FINDINGS:

1. Weight - postoperative - 10 lbs.
2. Gross Changes - There is no evidence of incision or surgery.

The edges of the previous wound is covered by a continuous smooth, glistening gingival epithelium which is pink-gray in color. There is no contrast of color between the tissues. It is rather difficult to distinguish the surgical site from the adjacent tissues. The oral mucosa is firmly attached to the body of the mandible. There is no discoloration of tissue in the adjacent area of the metallic implant. The surface texture of the gingiva, in comparison with the magnetic implant site, reveals that they are similar.

3. Metal - The metal remained unchanged; shows no discoloration; is non-corroded and is smooth and shiny.

B. HISTOLOGIC FINDINGS:

Epithelium: - The epithelial component of the mucosa covering the implant is absent.

Submucosa: - The connective tissue remaining consists of a fibrous connective tissue, muscle, and contains mucous glands. The mucoperiosteal flap is in immediate contact with the bone surface.

The periosteum is normally attached to the lateral surface of the mandible. The inner surface of the mucoperiosteal flap which lies directly over the defect is continuous with a fibrous connective tissue capsule. The mucoperiosteal flap appears normal. There is no cellular reaction of any type seen.

Bone: - The periosteum which is attached to the cut bone on the lateral surface nearest the implant is rounded off and shows a thickening. A few osteoblasts are seen on adjacent body surface.

The cut surface of the bony cortex shows resorption or reversal lines on which new bone has been apposed. Upon the newly apposed bone there is a dense fibrous periosteum which covers the cut surface. The actual diameter of the mandibular canal appears slightly reduced by this bridge of newly apposed bone. The

mandibular nerve, artery and vein are apparently normal. This bony bridge which was also observed at two months shows on its inner surface recent bone apposition. The surface of the bony bridge which lies directly beneath the capsule shows Howship's lacunae. There is some localized remodeling resorption going on in this new bone. The bone which is in immediate contact with the cut surface has been there for some time.

CHAPTER V

DISCUSSION

The sequence of histologic changes which occur in the lateral surface of the body of the mandible of a dog during a six-month period following the implantation of a magnet composed of platinum cobalt alloy (platinum 76.5% and cobalt 23.5%) in the shape of a flattened cylinder and possessing a magnet force of 3,283 oersteds is essentially normal healing of bone. The entire reaction was a connective tissue response:

- (1) The formation of a blood clot
- (2) Organization of the blood clot by proliferating young connective tissue and
- (3) The reconstructive process

The Inflammatory Response. The early reaction of the connective tissue and vascular system of bone to surgical injury induced in this study was only slight. The possibility of complete resolution appeared favorable at one month.

The reaction was characterized by hyperemia, formation of a blood clot, a fibrinopurulent type of exudate, the organization of the blood clot by proliferation of reserve or undifferentiated cells mobilizing from the

vital portions of the reactive loose connective tissue within the bone marrow and the mucoperiosteal flap; and the differentiation of these young connective tissue cells into more highly differentiated cells which carried out a reconstructive process leading to recovery.

Immediately following the initial injury the blood vessels which are injured hemorrhage and the blood penetrates into the defect. The injury was intensive enough to cause migration of leukocytes (polymorphonuclear leukocytes) forming in a fibrinopurulent type of exudate which filled the tissue spaces and encapsulating the metallic implant. This was the immediate defense reaction in response to injury. The exudate coagulated and caused the formation of a delicate irregularly arranged network of fibrin. This fibrin clot as seen from twenty-four hours to two weeks extended from the inner surface of the mucoperiosteal flap into the defect, continued into the mandibular canal and became continuous with the loose connective tissue of the bone marrow, thus encapsulating the implant. This fibrinous network first serves as an anchoring clot which glues together the injured tissues; then as a scaffolding for the formation of new tissue as it offers an excellent substrate for the invading new cells, and later becomes absorbed. The formation and undisturbed organization of this blood clot was of prime importance. This blood clot can be regarded as a perfect culture medium for the proliferating cells of the connective tissue which

invade it.

Twenty-four to forty-eight hours postoperative the alterations at the site of injury were essentially the same. Beginning at twenty-four hours the margins of the cut cortical bone surrounding the metallic implant showed evidence of necrosis of tissue of the Haversian canal; at forty-eight hours postoperatively, the lacunae nearest the marginal surface of the cut bone were empty and there was a contraction in the nature of the clot.

Connective Tissue Proliferation. It must be pointed out that before proliferation and differentiation of the reserve or undifferentiated cells take place, and prior to organization of the clot, a latent period is observed. Avery ('36) points out "that this latent period is variable, lasting between one or two days and four or five days. The length of this period can be readily prolonged or shortened depending upon the size of the wound and the type of stimuli applied. "

Sometime after forty-eight hours and prior to seventy-two hours, the reserve cells which comprise the loose connective tissue of the bone marrow and the connective tissue of the flap have undergone proliferation and differentiation as there is essentially no significant difference seen in the fibrin clot at forty-eight hours. The assumption is that desoxyribonucleic acid (DNA) synthesis, and mitosis leading to proliferation and differentiation as evidenced by the appearance of osteoclasts, osteoblasts,

and histiocytes must occur between forty-eight and seventy-two hours.

Seventy-two hours postoperative marked the beginning of a transition from the temporary mechanism of an anchoring blood clot into an organized blood clot. From the vital portions of the reactive connective tissue surrounding the metallic implant, mainly, from within the loose connective tissue of the bone marrow and from the inner surface of the mucoperiosteal flap reserve cells begin proliferating and infiltrate into the clot, and the cut surface of the bone.

The essential feature seen at seventy-two hours not seen at twenty-four or forty-eight hours were:

- (1) The proliferation of reserve cells with large nuclei and ill-defined cytoplasm,
- (2) The budding of new capillaries,
- (3) Phagocytosis of hemosiderin granules as seen within the cytoplasm of macrophages, and
- (4) The presence of osteoclasts on the outer cut cortical surface of bone and osteoblasts on the inner surface.

The Reconstructive Process. As early as twenty-four hours an infiltration of polymorphonuclear leukocytes invaded the blood clot, the inner surface of the mucoperiosteal flap and the peripheral surface of the loose connective tissue of the bone marrow. These cells eventually de-

generated or underwent necrosis and were gradually replaced by macrophages which mobilized from the vital portions of the reactive connective tissue. Simultaneously, the edematous fluid was reabsorbed and removed by blood vessels and lymph vessels, so that at the end of one month there was complete absence of inflammatory cells and a normal attachment of the body of the mandible.

Early resorption of the cut bony surfaces was achieved only by osteoclastic activity. Osteoclasts began within seventy-two hours and became most active between nine days eight hours, and fourteen days. The result was resorption of the sharply cut margins of bone and the small minute bony spicules seen within the fibrin clot. While osteoclastic resorption was still a prominent feature, osteoblastic activity began as in nine days eight hours new bone was identified, and in two weeks a vigorous apposition of bone tissue in the cancellous bone was observed. This new bone was identified as osteoid tissue outlining the trabeculae.

Between nine days eight hours and two weeks cellular activity continued beyond what was seen at seventy-two hours. Furthermore, this period was characterized by less proliferation of cells and more differentiated cells. Fibroblasts with the production of collagenous fibers, the budding of many new capillaries forming within the clot, histiocytes (macrophages) phagocytizing particles of hemosiderin, osteoclasts resorping bone,

osteoblasts apposing new bone all of which are conclusive factors indicative of the reconstructive process. Nine days eight hours was the first time that showed definite evidence of fibroblastic activity. The proliferation was indicated by the increase number of fibroblasts and the formation of collagenous fibers around the implant.

While regeneration of all tissues, including bone occurred during the reconstructive process, the most significant microscopic finding at the end of one month was that under the influence of the fibroblasts, the immature collagenous fibers were organized into mature collagenous fiber bundles. These mature collagenous fibers were arranged in interwoven bundles parallel to the long axis of the bone, and served as a dense fibrous connective tissue capsule which lined the inner surface of the mucoperiosteal flap and became continuous with the periosteum then extended deep into the marrow space covering the previously cut surface of the defect, thus encapsulating the metallic implant and separating it from the mandibular canal and the cut surface of the bone. The outstanding features of this adoption in the form of a dense fibrous connective tissue served a dual purpose:

- (1) On the surface opposing bone it serves as a fibrous periosteum, as it is a source of osteoclasts and osteoblasts, as remodeling and resorption on the

other surface of the bony bridge continues at six months, and

- (2) On the outer surface it encapsulates the metallic plant.

Osteoclasts which differentiated from the vital reactive connective tissue of the bone marrow and from the inner surface of the mucoperiosteal flap began a process of resorption on the cut surface of the bone, removing the non-vital bone. This activity diminished considerably between nine days eight hours and two weeks, as little activity was observed at one month. However, remodeling, by resorption and apposition continued throughout the six months, as beginning with one month the fibrous capsule encapsulating the implant served as a source of the osteoclasts and osteoblasts.

Wherever bone forms, special bone-building cells the osteoblasts must be present as these cells alone have the capacity to form bone. Sicher and Weinman (1955) point out "that formation of bone can occur only if two conditions are fulfilled: (1) the presence of cells of low differentiation and therefore of high potentiality, and (2) an adequate stimulus to induce these pluripotential cells to differentiate into osteoblasts." Osteogenesis began with the appearance of the osteoblasts at seventy-two hours which was almost simultaneously with the appearance of the osteoclasts. Osteoblasts,

like osteoclasts differentiated from proliferating reserve cells of the loose connective tissue of the bone marrow and from the mucoperiosteal flap. Thus in the process of healing of bone, cells in the periosteum, endosteum, and bone marrow under the stimulus of trauma reassume the form of osteoblasts and once again are actively engaged in osteogenesis.

The apposition of bone tissue occurred first in the deeper bone marrow spaces and continued throughout the six months. As osteoclastic activity declined from nine days eight hours osteoblastic activity increased, so that at the end of two months a bony bridge was formed completely separating the mandibular canal from the defect.

A unique feature of the entire study was the lack of a foreign body reaction. Inflammation being the local reaction of the living tissues to an irritant. No matter, therefore, how aseptic an operation may be, it must inevitably be accompanied by some degree of inflammation. The polymorphonuclear leukocytes, the characteristic cell of acute inflammation with phagocytic properties, appeared in the injured tissue and formed the first line of defense. Macrophages or histiocytes another cell of inflammatory response with great phagocytic power appeared in the later stages of inflammation by phagocytizing tissue debris and fibrin. They played a definite part in the destructive phase of healing. However, during the sequence of healing there was complete absence of any multinucleated giant

cells in the tissues encapsulating the implant. The significance of this finding would indicate that a metallic implant composed of platinum cobalt alloy is inert. It merely occupies space, affecting in no way the regeneration of bone and periosteum.

Another important clinical consideration is the effect of magnetism upon the healing of a bony defect, and oral mucosa. Although a metallic implant composed of platinum cobalt alloy (platinum 76.5% and cobalt 23.5%) was magnetized to 3,283 oersteds the connective tissue response around such an implant was essentially the same as that around a non-magnetic metallic implant. This observation is indicative that platinum cobalt alloy is well tolerated by tissue, most important is that the evidence that magnetism has no effect upon tissue as seen by histological methods used in this investigation.

The microscopic studies of these specimens as might be expected, offer a far better basis for conclusion than mere gross inspection. Of the ten dogs operated upon an average net weight loss of three and eight tenths pounds was noted, and as a result of pneumonia two dogs died; one forty-eight hours and the other one month two weeks. A third dog became ill with pneumonia and was sacrificed at nine days eight hours.

Examination of the gross specimens revealed a minimal amount of edema and swelling of the gingival tissues along the site of surgery which

was present up to nine days eight hours. For a period of three days the approximated tissue edges along the line of incision appeared reddened, rolled, and elevated with a coagulated hemorrhagic exudate in the form of a clot linking them together. Where the oral mucosa and periosteum was completely separated from the body of the mandible food debris and dog hairs had accumulated. At nine days eight hours healing was almost complete. The oral mucosa overlying the implant was smooth and somewhat attached to the body of the mandible. The rolled edges had disappeared and a few sutures along a shallow depressed line indicated the previous incised edges. The color of the oral mucosa was a pink-gray.

By the end of one month complete healing was observed. The muco-periosteal flap was firmly attached to the mandible and the necks of the teeth making it extremely difficult to distinguish it from the adjacent tissue. After six months of implantation of this metallic implant composed of platinum cobalt alloy in the lateral surface of the body of the mandible of a dog revealed a complete lack of discoloration of the surrounding tissue and the metal remained smooth and shiny, and it was impossible to tell which tissue approximated the non-magnetic implant and which approximated the magnetic implant.

Comparison With Other Studies. Since the study carried out by Behrman (1960) is not supported by histologic findings and yet it is the

closest to the present one in its design, it is of interest to compare our findings to the views expressed by Behrman. The present investigation does verify his report that a bony growth takes place, but not around the edges of the implant, which Behrman claims aids in the retention of the implant. The findings of this study revealed that bone apposition does take place on the cut surfaces of bone, and that the actual intimate contact with the implant is by a dense fibrous capsule which encapsulates the implant and serves as a fibrous periosteum. However, there is evidence of some osteoblasts directly overlying the newly apposed bone as resorption and remodeling of the bone continues at six months.

Suggestions for further study. The connective tissue response of the bone and its surrounding structures was the most significant finding of this investigation. It was possible to predict this response following one month postoperative study. This study of the effects of a magnetic metal composed of platinum cobalt alloy upon the healing of bone defect during a six month implantation should be followed by a study of actual situations of effective magnetic implantation. The cells participating in the formation of bone should be definitely identified and the amount of bone resorption should be analyzed.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This investigation was designed to study the response of the oral mucosa and bone in dogs to a magnetic implant composed of platinum cobalt alloy, and to ascertain the possible effects of magnetism on the repair process.

Ten young adult, apparently normal, mongrel dogs with complete dentition were used as experimental animals. A sterile magnetic implant composed of platinum cobalt alloy (platinum 76.5% and cobalt 23.5%) in the shape of a flattened cylinder measuring 6.35 mm (in length) x 3x55 mm (in height) x 2.54 mm (in width) which is capable of sustaining a load of 100 grams and possess a magnetic force of 3,283 oersteds was implanted in the lateral surface near the inferior border of the mandible between the lower left fourth premolar and lower left first molar.

Four animals served as control specimens in which four sterile non-magnetic platinum cobalt alloy implants of corresponding size were implanted in a comparable area of the opposite side. Each animal was operated upon in the same manner.

By means of a lethal dose of sodium pentobarbital these dogs were

sacrificed, and in a sequence of a period of time from twenty-four hours to six months histologic studies have been made. The microscopic specimens secured in this manner gave evidence of the entire process of tissue healing.

The response of the oral mucosa and bone to a metallic magnetic implant in the mandible of a dog was studied. The behavior of the blood clot was noted and the progress of healing of the defect was observed. Clinical observations revealed that healing took place rather rapidly. In the beginning the wound surface had a grayish-colored blood clot, and later, a red, velvety granulation tissue. At the end of the six-month period, the gross appearance indicated no significant change in the oral tissues. The implants remained firmly in place, and the animals seemed to be totally unaffected by their presence. No oral lesions were encountered, the major defect observed being hyperemia and hemorrhage. Death occurred at forty-eight hours, nine days eight hours; and one month two weeks, as a result of pneumonia. Histological investigation of the defect revealed the progress that occurred from the formation of the blood clot to the complete healing of the defect. The reaction of the connective tissue proved to be of great interest.

It was found that:

1. The entire reaction was a connective tissue response of

normal healing.

2. The blood and its elements in wound healing must be considered. The migrating leukocytes and red blood corpuscles, which enter the tissues during hemorrhage, and especially fibrin which plays an important part in encasing the implant in the wound area are all essential factors in wound healing.
3. The blood clot can be regarded as a perfect culture medium for the proliferating cells of the connective tissue which invade it.
4. Histiocytes (macrophages), by phagocytizing tissue debris and fibrin play a definite part in the destructive phase of healing of the defect. Possibly the neutrophils are active also in removing the smaller particles.
5. The acuteness of the inflammatory reaction diminished as the healing of the defect progressed.
6. New bone formation was greatest between nine days eight hours and one month. As osteoclastic activity declined from nine days eight hours; osteoblastic activity increased, so that at the end of two months

a bony bridge was formed completely separating the mandibular canal from the defect.

7. The inner most surface of the mucoperiosteal flap; that is, at the margins where it is in contact with cut cortical bone, serves as a source of osteoclasts and osteoblasts.
8. The most significant findings were; one, in a repair process mitosis and proliferation is the first step, followed by differentiation then organization. --
Between forty-eight hours and seventy-two hours post-operative, the proliferating reserve cells from the loose connective tissue of the bone marrow and from the mucoperiosteal flap differentiated into more highly differentiated or specific cells such as, the osteoclasts, osteoblasts, histiocytes and fibroblasts which carry on a reparative process leading to recovery.
Second, the formation of a dense fibrous connective tissue capsule encapsulating the implant. --
The adoption of the dense fibrous connective tissue capsule serves a dual purpose; on the surface apposing bone it serves as a fibrous periosteum as it is a

source of osteoclasts and osteoblasts as remodeling and resorption on the outer surface of the bony bridge continues at six months. On the outer surface it encapsulates the metallic implant.

9. The metallic implant composed of platinum cobalt alloy is inert, the metal merely occupies space affecting in no way the regeneration of the bone; it is well tolerated in the mandible of the dog, as evidenced by a complete absence of any foreign body giant cells. Most important is that magnetism has no effect upon the sequence of normal healing as seen by histological methods used here.
10. At the end of the six month period, the gross appearance indicated no significant change in the oral tissues. The implants remained firmly in place, and the animals seemed to be totally unaffected by their presence.
11. Roentgenograms of the specimens showed close adaptation of the implants.

Further study of actual situations of effective magnetic implantation with clinical application should follow this investigation.

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PLATE VIII

Figure 9. A sterile magnetic implant magnetized through its diameter composed of platinum-cobalt alloy (platinum 76.5% and cobalt 23.5%) which is capable of sustaining a load of 100 grams and possess a magnetic force of 3,283 oersteds. It measures 1/4 inch in length, a little more than 1/8 inch in width and less than 1/8 inch in depth (precise dimensions of the implant are 6.35 x 3.55 x 2.54 mm).

The implants are packed individually in benzalkonium chloride in small glass jars. They should be handled only with sterile instruments and if contaminated, they should be resterilized by soaking for at least 18 hours.

APPENDIX

A. Photographs of Methods and Materials

PLATE VIII



Figure 9

PLATE IX

Figure 10. Photograph of the metal implant showing comparable size. Each composed of platinum-cobalt alloy (Pt. 76.5% and Co 23.5%).

Precise dimensions of the implants are 6.35 mm in length, 3.55 mm in width and 2.54 mm in depth.

Magnetic implant (right), possess a magnetic force of 3,283 oersteds, and a magnetic field of 12.772 Cm³.

$$(1) \text{ Magnetic Force: } F_0 = \frac{1}{D^2} \text{ (cm)}$$

$$(2) \text{ Magnetic Field: } V = \frac{4}{3} \times \pi r^3$$

Weight of the implants = 0.7677 grams.

PLATE IX

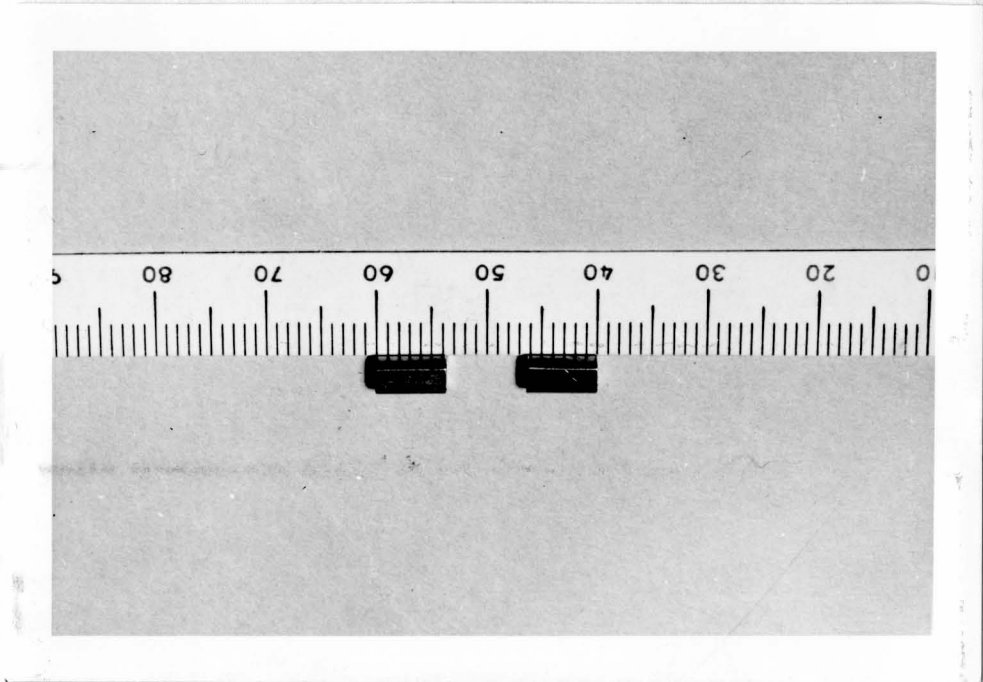


Figure 10

PLATE X

Figure 11. Color photograph of Dog No. 2, young female adult mongrel dog, approximately 2 years of age showing pigmentation of the attached gingiva and absence of pigmentation in the free gingiva. Note the stippling in the attached gingiva and the prominent vertical fold between the necks of the teeth. Site of implant is between the lower left fourth pre molar and the lower first molar. All photographs in this series were taken from living animals unless otherwise stated.

Figure 12. Color photograph showing initial incision with a number 11 blade mounted on Bard Parker scapel. Incision being made through the attached gingiva distal to canine and extending to the second molar area.

PLATE X



Figure 11

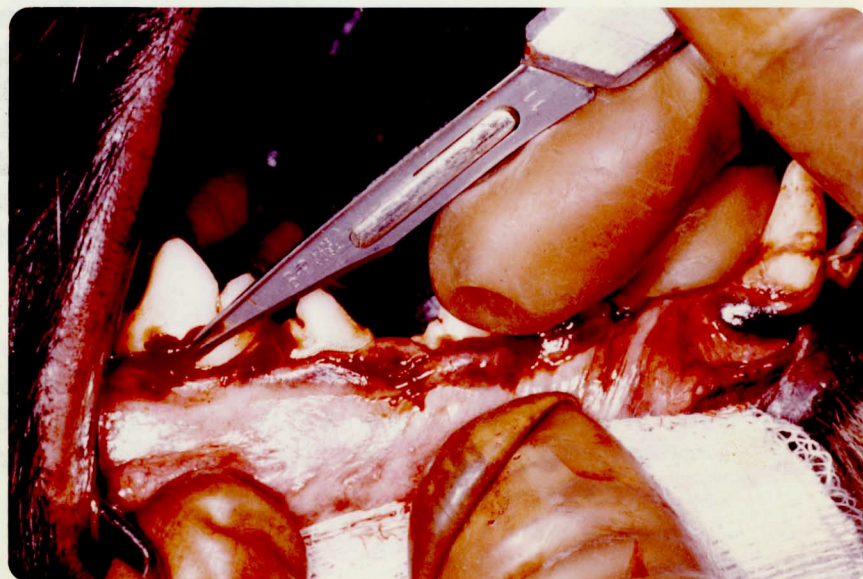


Figure 12

PLATE XI

Figure 13. Color photograph of Dog No. 1 showing muco-periosteal flap.

Figure 14. Color photograph of Dog No. 1 showing No. 557 carbex fissure bur mounted in a dental hand piece in position for preparation of bony vault on the lateral surface near the inferior border of the body of the mandible between lower left fourth pre molar and lower left first molar.

PLATE IX

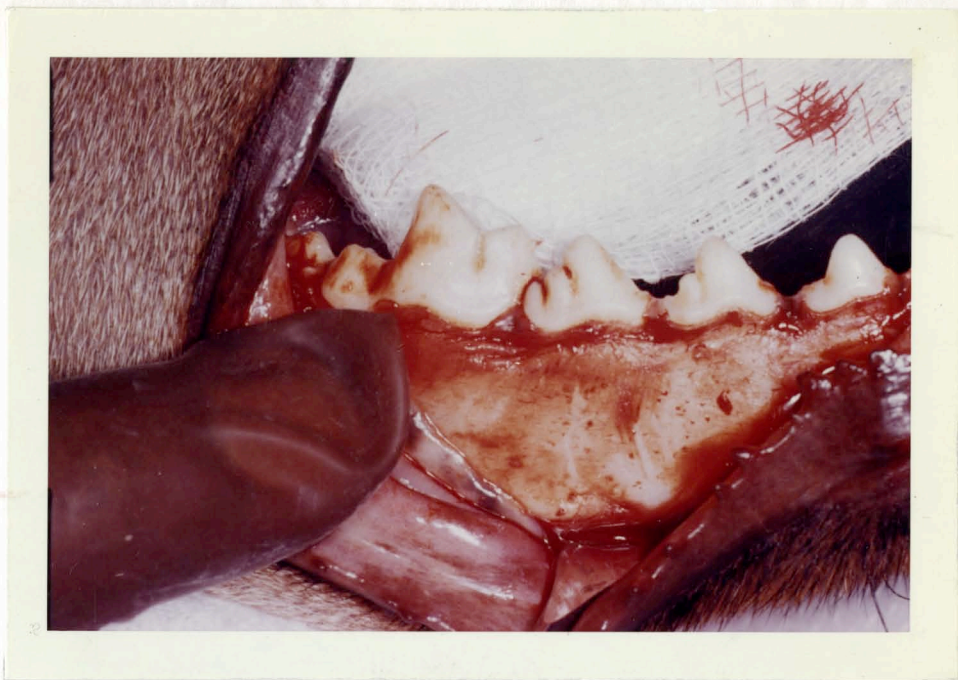


Figure 13

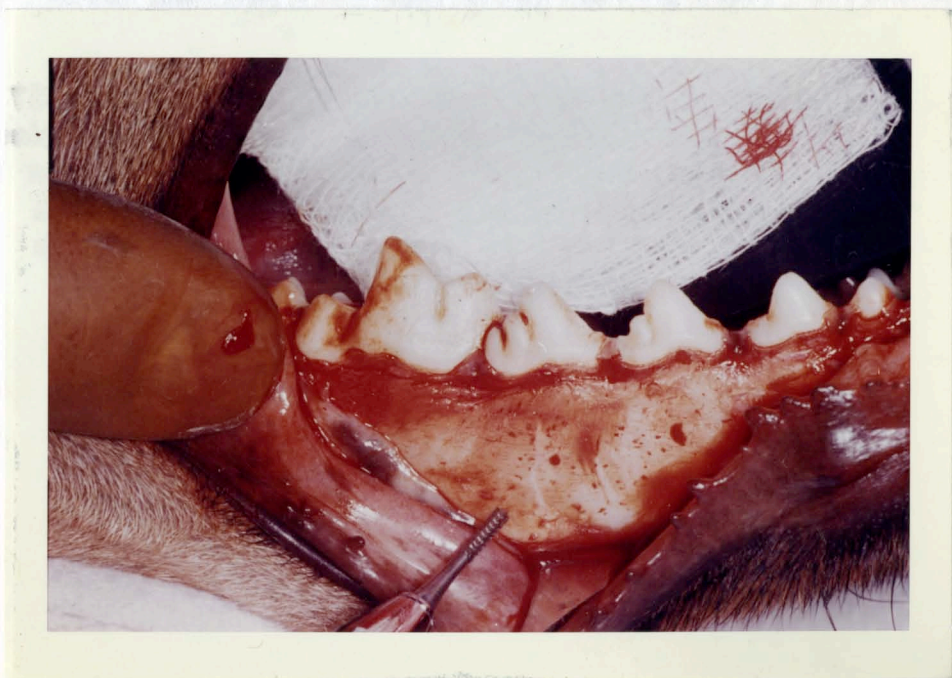


Figure 14

PLATE XII

Figure 15. Color photograph of dog No. 1 showing initial start of bony vault in the cortex at the inferior border of the mandible.

Note: mandibular nerve.

Figure 16. Color photograph of Dog No. 3 showing platinum-cobalt magnetic implant in place.

Note site: inferior border of mandible, between lower left fourth pre molar and lower left first molar.

PLATE XII

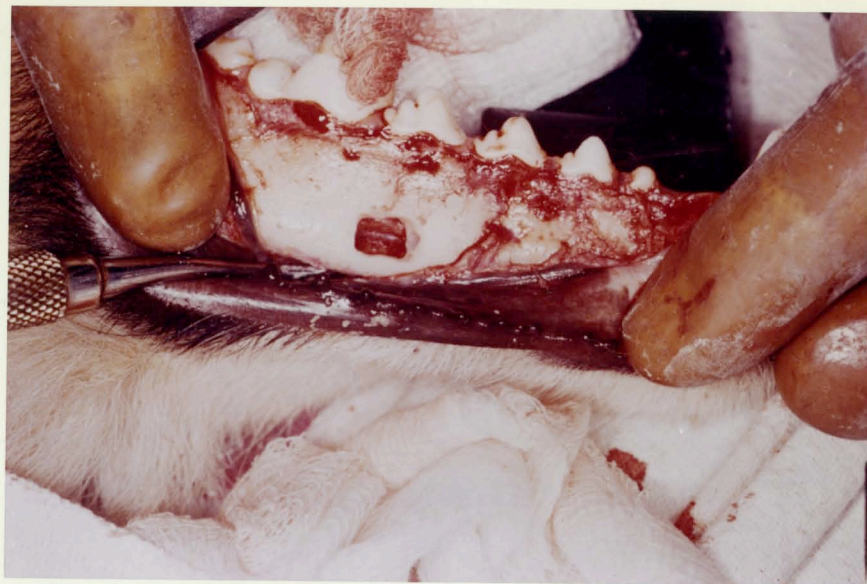


Figure 15

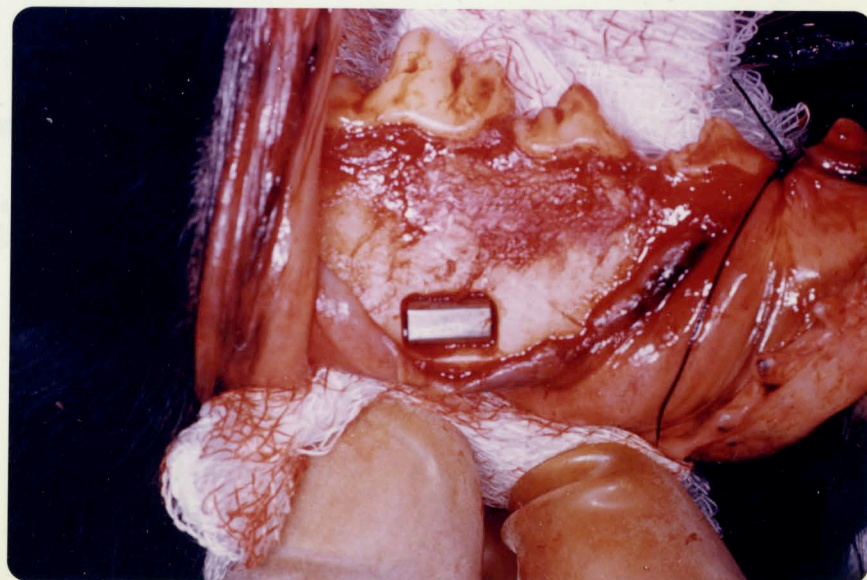


Figure 16

PLATE XIII

- Figure 17.** Color photograph of Dog No. 2 showing platinum-cobalt non magnetic implant in place.
Note site: inferior border of mandible between lower right fourth premolar and lower right first molar.
- Figure 18.** Color photograph of Dog No. 2 showing platinum-cobalt magnetic implant in place.
Note site: inferior border of mandible between lower left fourth premolar and the lower left first molar.

PLATE XIII

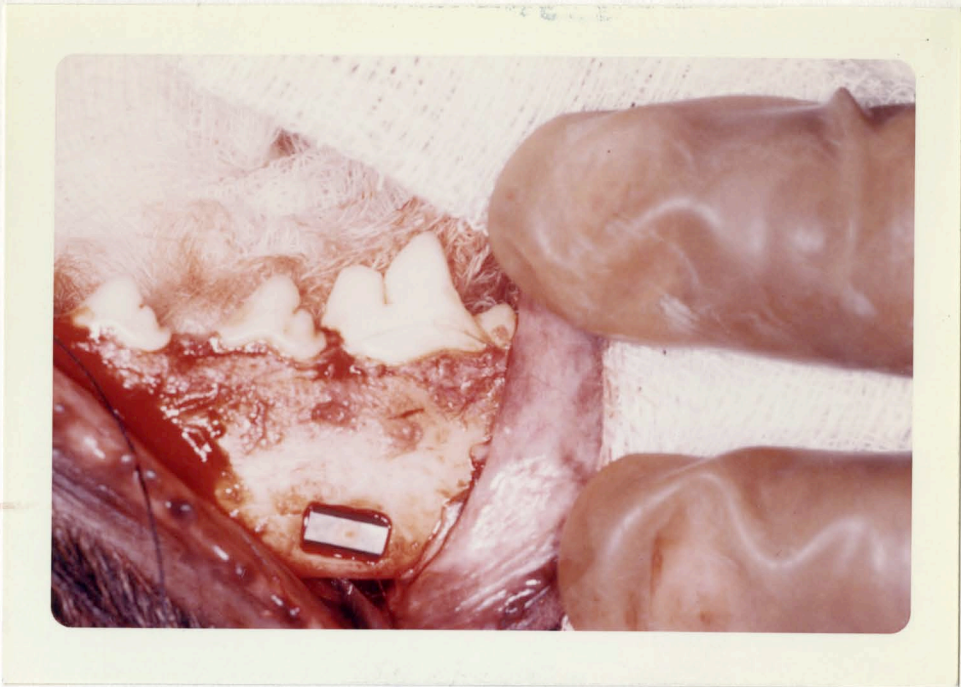


Figure 17



Figure 18

PLATE XIV

Figure 19. Color photograph of Dog No. 4 showing completed bony vault prior to insertion of implant. Bony vault measuring approximately 6.5 mm in length and 3.5 mm in height.

Note: flap design as compared to figure 11.

Figure 20. Color photograph of Dog No. 4 showing platinum-cobalt magnetic implant in position so that it is flush or slightly below the margins of the vault.

PLATE XIV

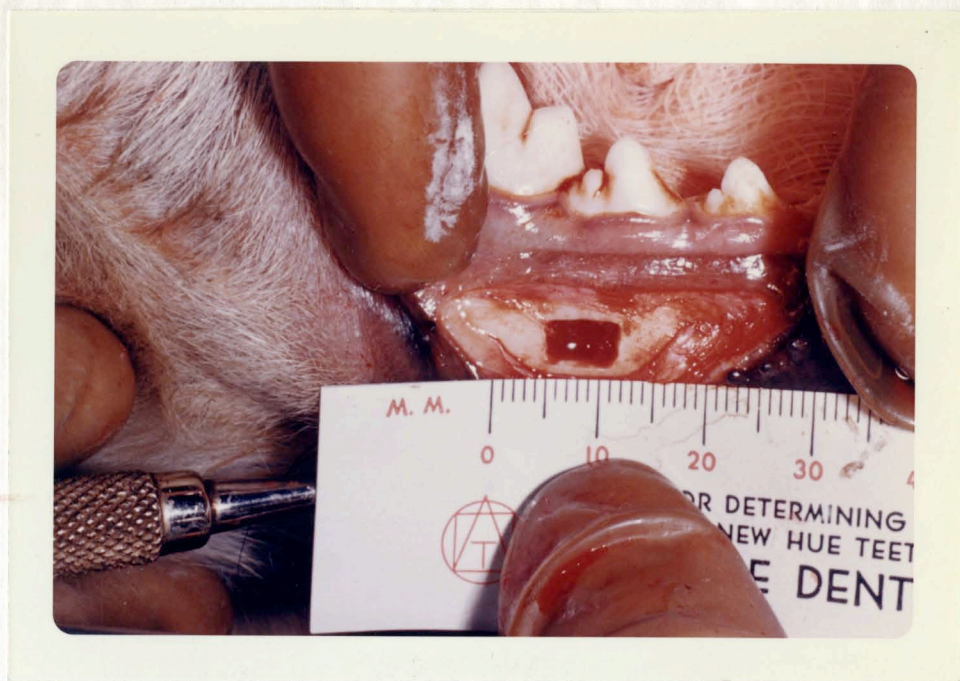


Figure 19



Figure 20

PLATE XV

Figure 21. Color photograph of Dog No. 1 showing post operatively the mucosa re-approximated to its normal position to cover implant and sutured to place using several interrupted 000 (triple 0) silk suture.

Figure 22. Color photograph of Dog No. 4 showing variation in the surgical closure. Incision was made in the buccal sulcus and the gingiva was reflected upward toward the crest of the alveolar process.

Note: compare figure 21 with figure 22.

PLATE XV



Figure 21



Figure 22

PLATE XVI

Figure 23. Color photograph of Dog No. 5. Two weeks post operatively.

Note: (1) One suture remains over the line of incision between the proximal surface of lower left second and third premolar. (2) The oral mucosa is rather firmly attached to the body of the mandible. (3) The gingiva, pink in color, is smooth with a glistening appearance.

Figure 24. Color photograph of Dog No. 1. The mandible was removed surgically by means of a gigli saw.

PLATE XVI



Figure 23



Figure 24

PLATE XVII

Figure 25. Photomicrograph X 100 of twenty-four hour specimen showing the blood clot serving as an anchoring clot which glues together the injured tissues.

B. Photomicrographs

PLATE XVII

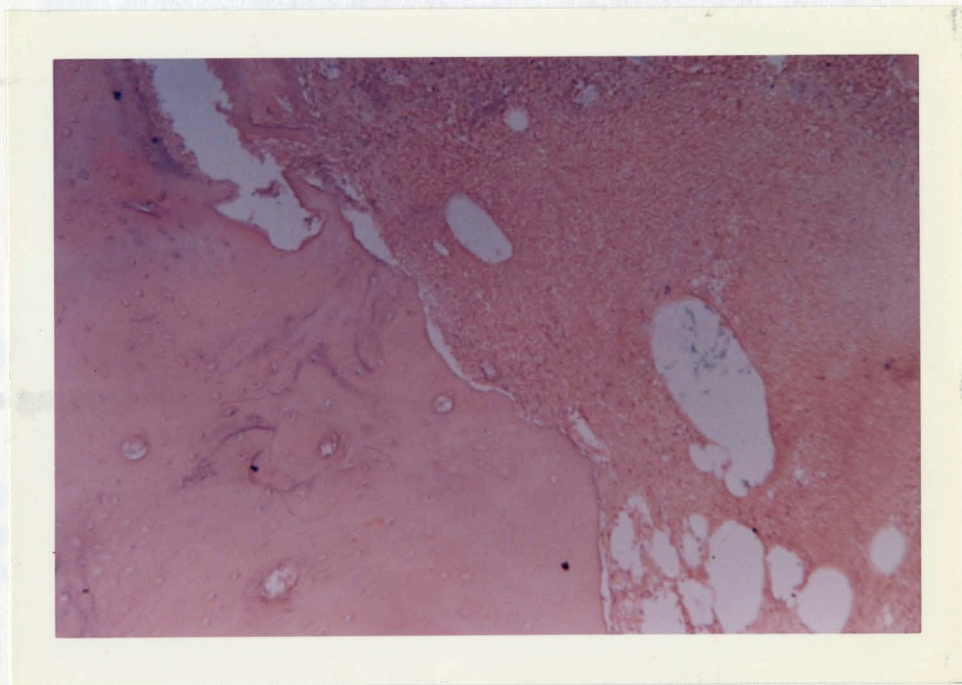


Figure 25

PLATE XVIII

- Figure 26. Photomicrograph X 100 of forty-eight hour specimen showing blood clot.
- Figure 27. Photomicrograph X 400 of figure 26 forty-eight hour specimen showing acute inflammation; leukocytic exudate, made up almost entirely of polymorphonuclear leukocytes, red blood cells, and minute spicules of bone.

PLATE XVIII

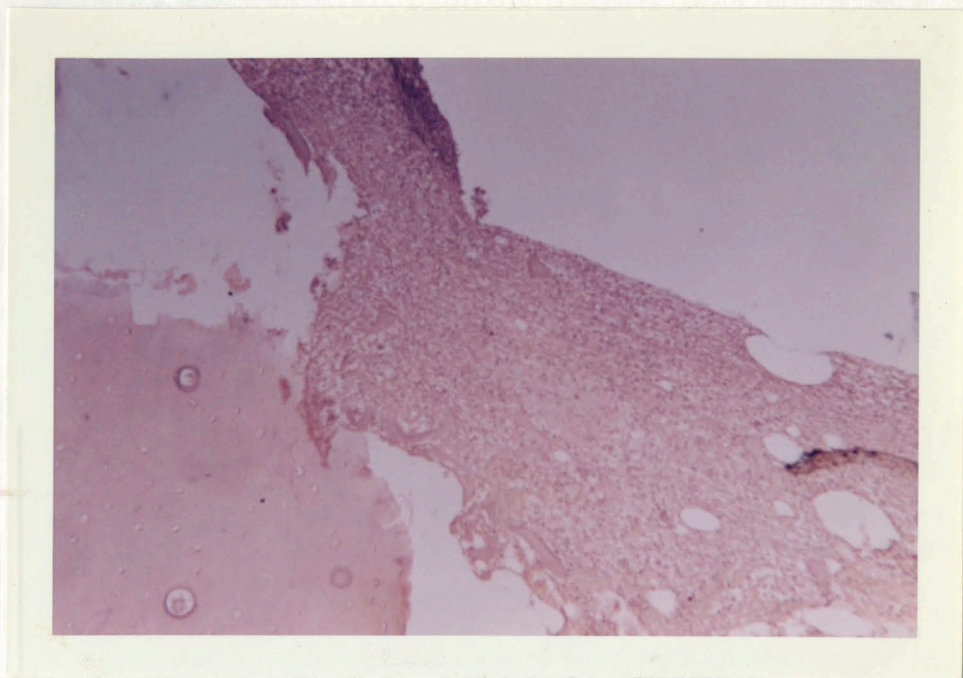


Figure 26

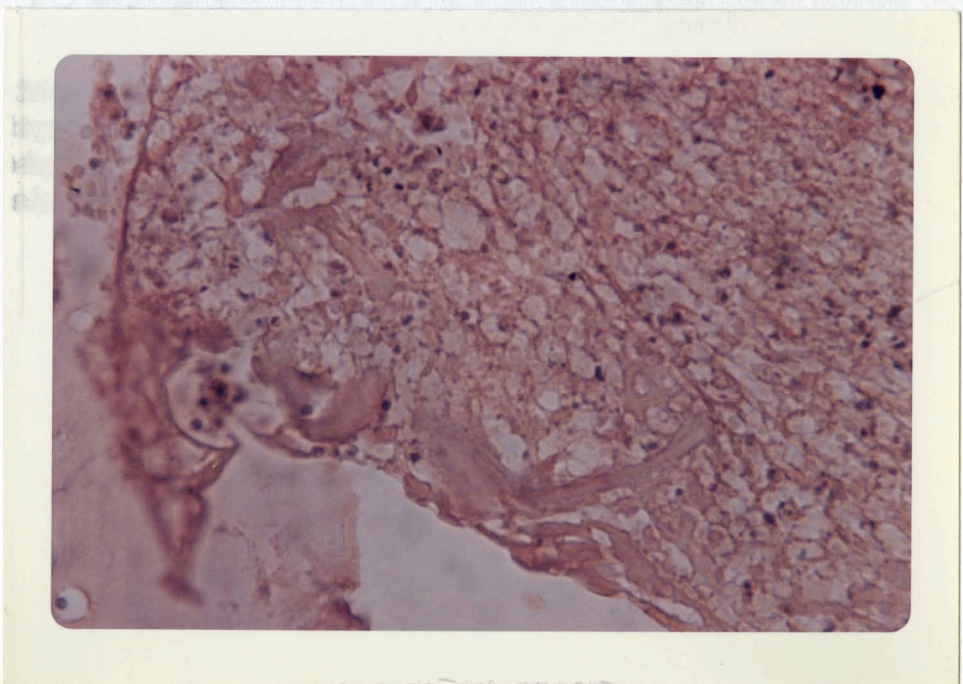


Figure 27

PLATE XIX

Figure 28. Photomicrograph X 100 of forty-eight hour specimen showing the formation of a delicate irregularly arranged network of fibrin in proximity to bone.

PLATE XIX

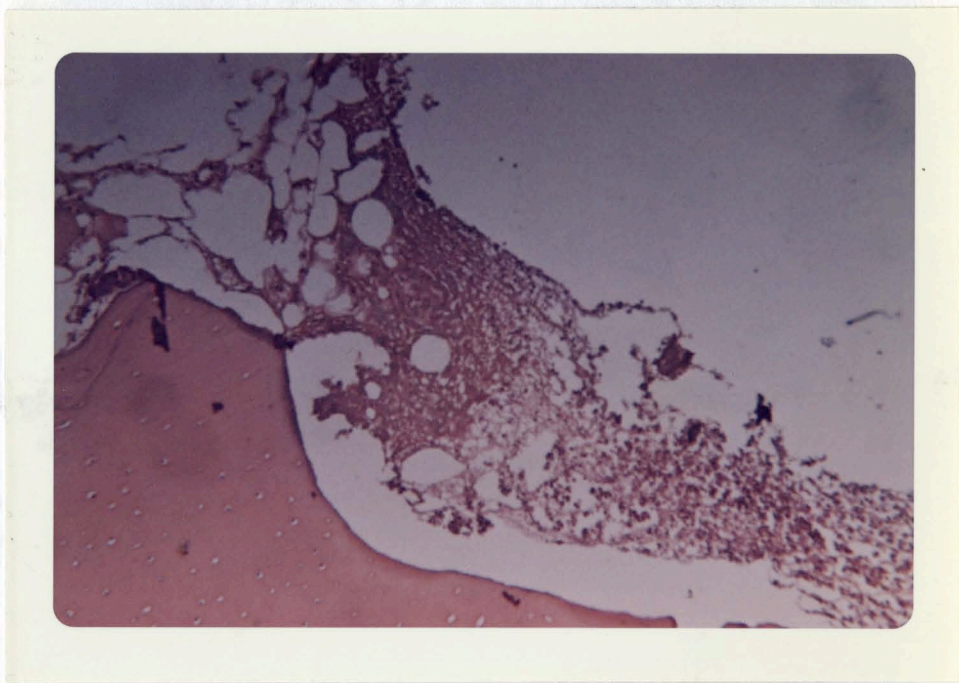


Figure 28

PLATE XX

Figure 29. Photomicrograph X 900, seventy-two hours specimen showing mitotic activity in the reserve cell or undifferentiated cell.

Figure 30. Photomicrograph X 900, seventy-two hours specimen showing proliferation of the reserve or undifferentiated cells prior to differentiation.

PLATE XX

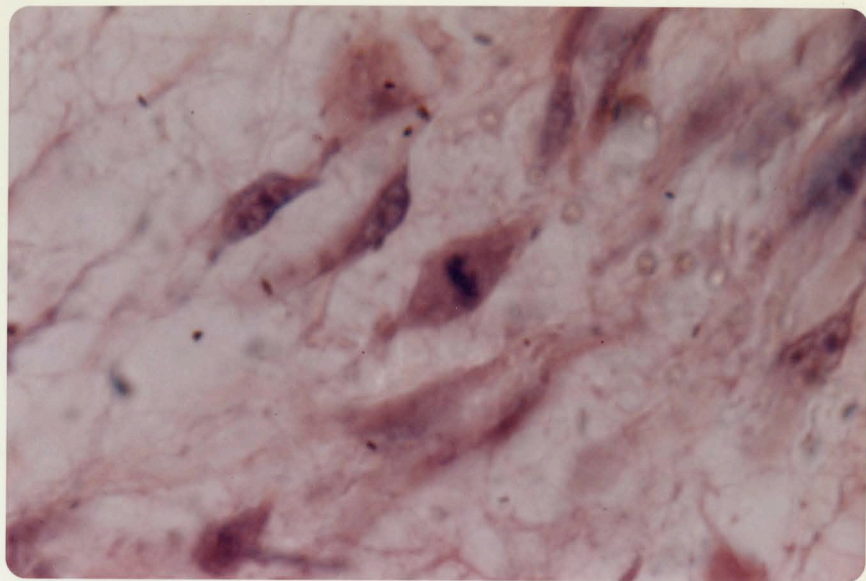


Figure 29

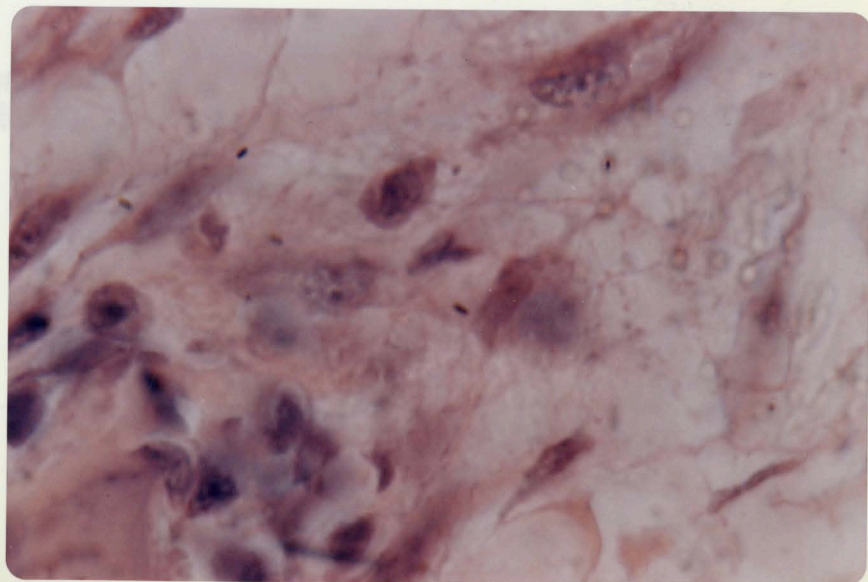


Figure 30

PLATE XXI

Figure 31. Photomicrograph X 100 seventy-two hour specimen showing the beginning of a transition from the temporary mechanism of an anchoring blood clot into an organized blood clot. Cellular reaction begins from within the loose connective tissue of the bone marrow, cells begin to proliferate and infiltrate into the clot, and the cut surface of the bone.

Figure 32. Photomicrograph X 400 of figure 31 seventy-two hour specimen showing organizing connective tissue.

Note: (1) Osteoclasts and osteoblasts on the bony surface (2) Inflammatory cells present in the loose connective tissue.

PLATE XXI

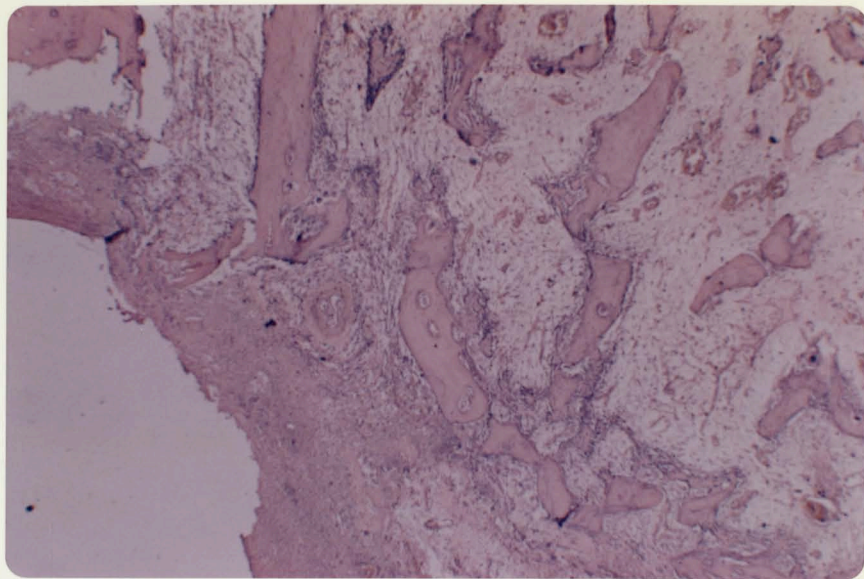


Figure 31

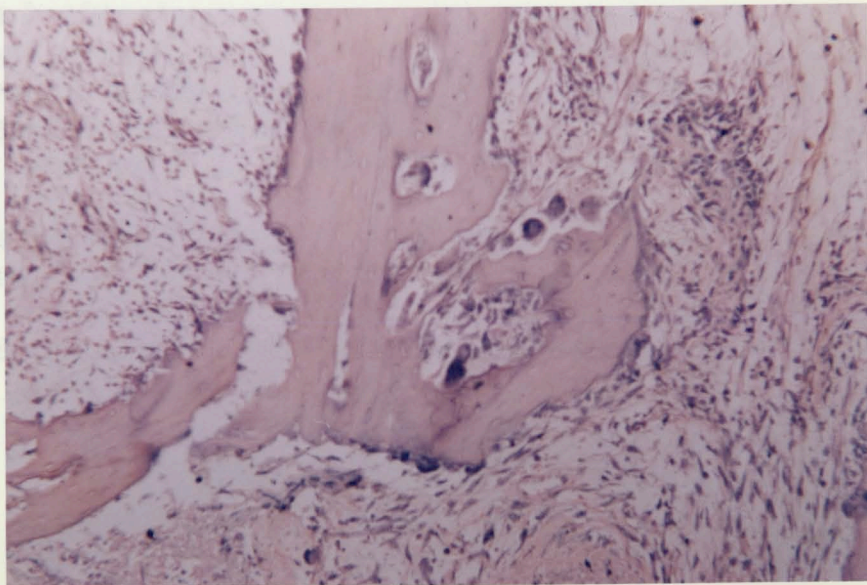


Figure 32

PLATE XXII

Figure 33. Photomicrograph X 400 seventy-two hour specimen showing proliferation of reserve cells and differentiation of osteoclasts and cuboidal osteoblasts.

Figure 34. Photomicrograph X 900 of figure 33 seventy-two hour specimen showing organizing connective tissue bed.

Note: (1) The presence of osteoclasts on the edges of the bone. (2) Cuboidal osteoblasts on the edges of the bone and (3) The formation of a delicate irregularly arranged network of fibrin.

PLATE XXII

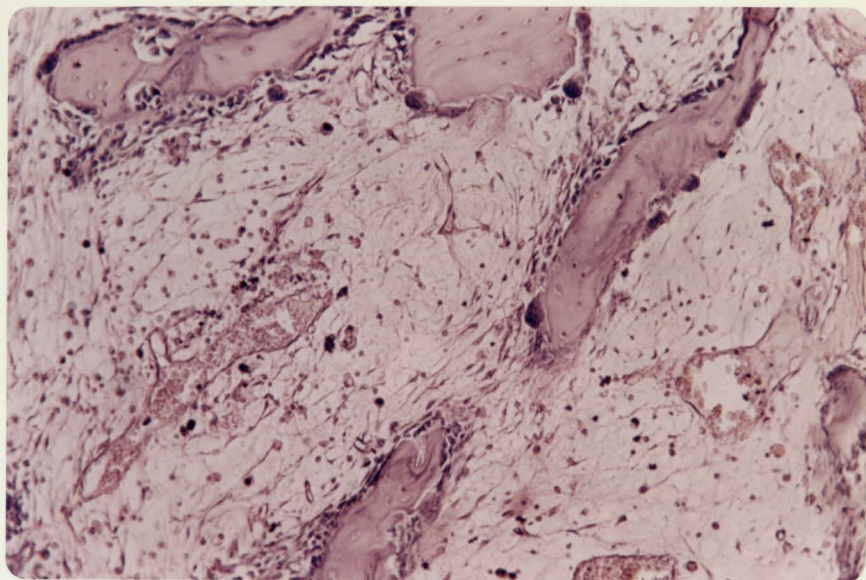


Figure 33

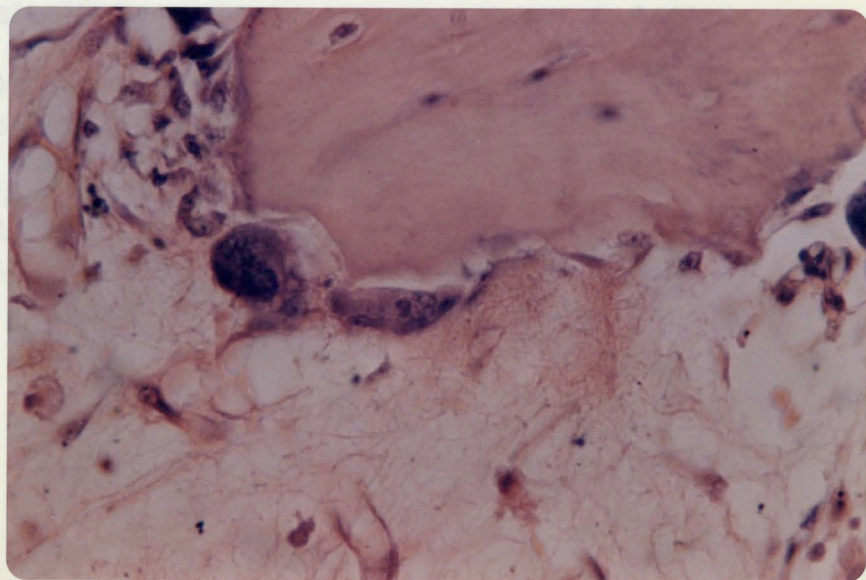


Figure 34

PLATE XXIII

Figure 35. Photomicrograph X 900 nine days eight hour specimen showing proliferation of reserve connective tissue cells and differentiation of young fibroblasts.

Figure 36. Photomicrograph X 900 nine days eight hour specimen showing the gradual appearance of endothelial sprouts of new capillaries.

PLATE XXIII

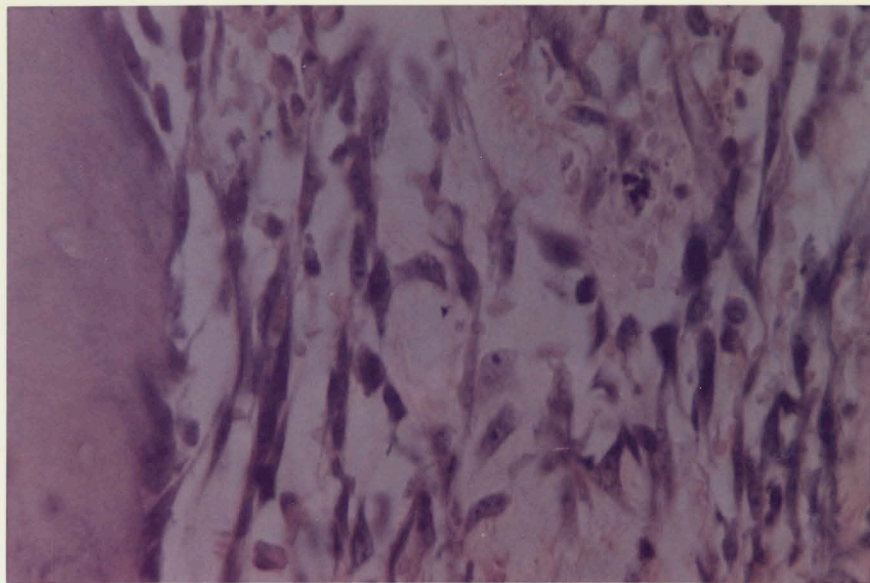


Figure 35

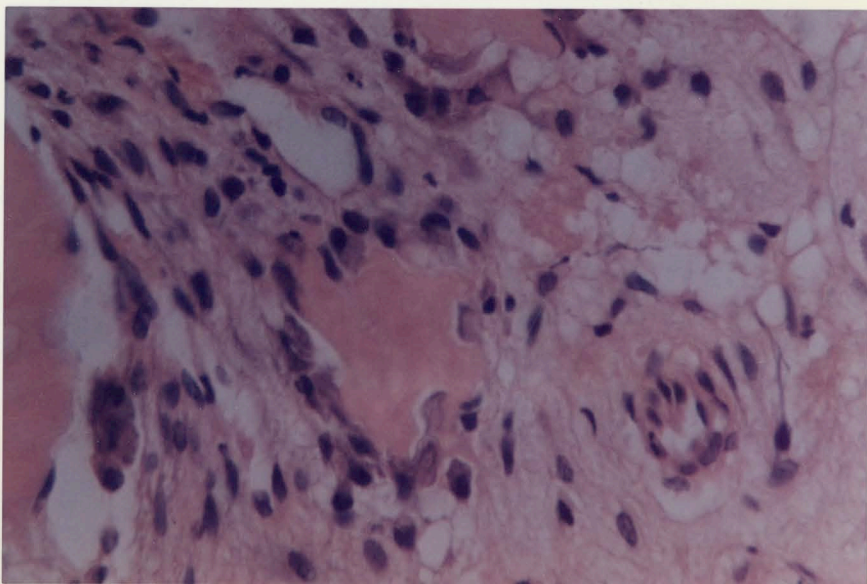


Figure 36

PLATE XXIV

Figure 37. Photomicrograph X 900 nine days eight hour specimen showing osteoclastic activity removing the non-vital bone.

Figure 38. Photomicrograph X 900 nine days eight hour specimen showing histiocytes (macrophages) phagocytizing particles of hemosiderin.

PLATE XXIV

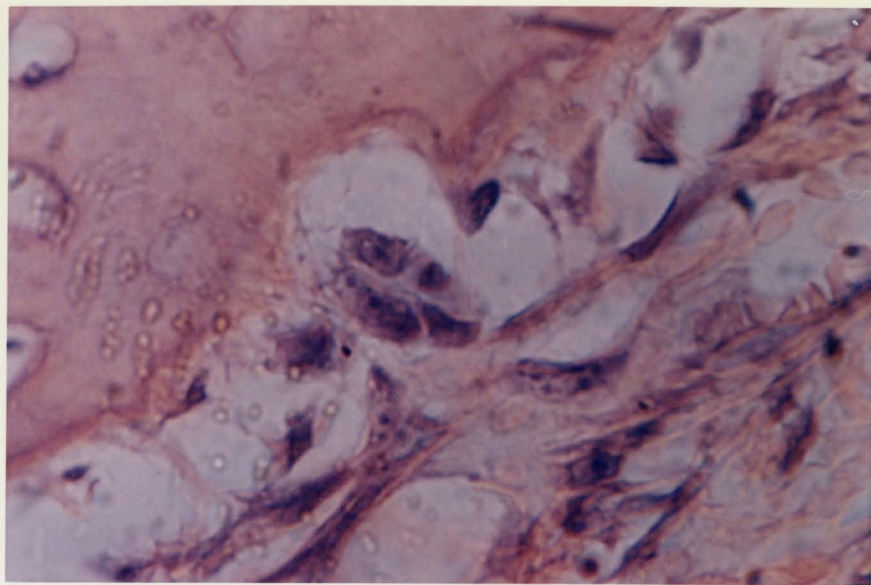


Figure 37

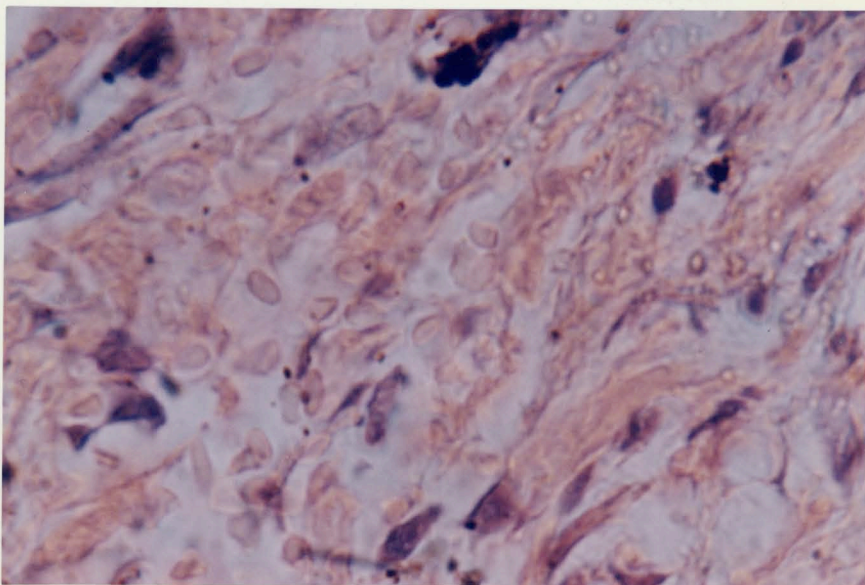


Figure 38

PLATE XXV

Figure 39. Photomicrograph X 900 two week specimen showing organization of the fibrinous blood clot.

Note: (1) Spindle-shaped parallel-arranged fibroblasts, (2) macrophages or histiocytes, (3) budding of new capillary.

Figure 40. Photomicrograph X 900 two week specimen showing capillary in organizing blood clot. Histiocytes, plasma cells, fibroblasts and delicate collagenous fibers are evident.

PLATE XXV

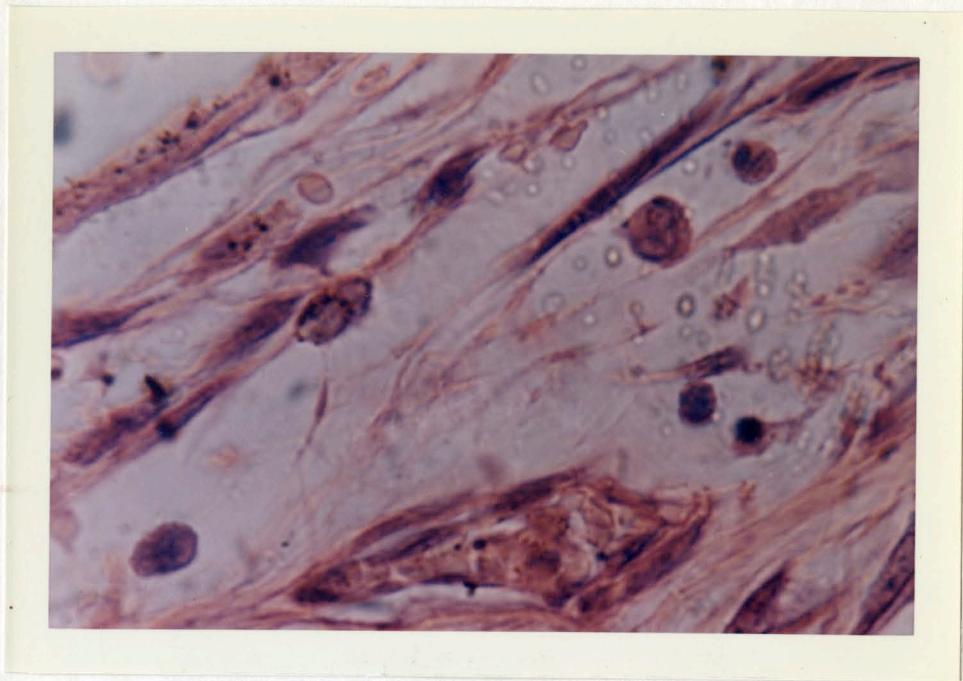


Figure 39

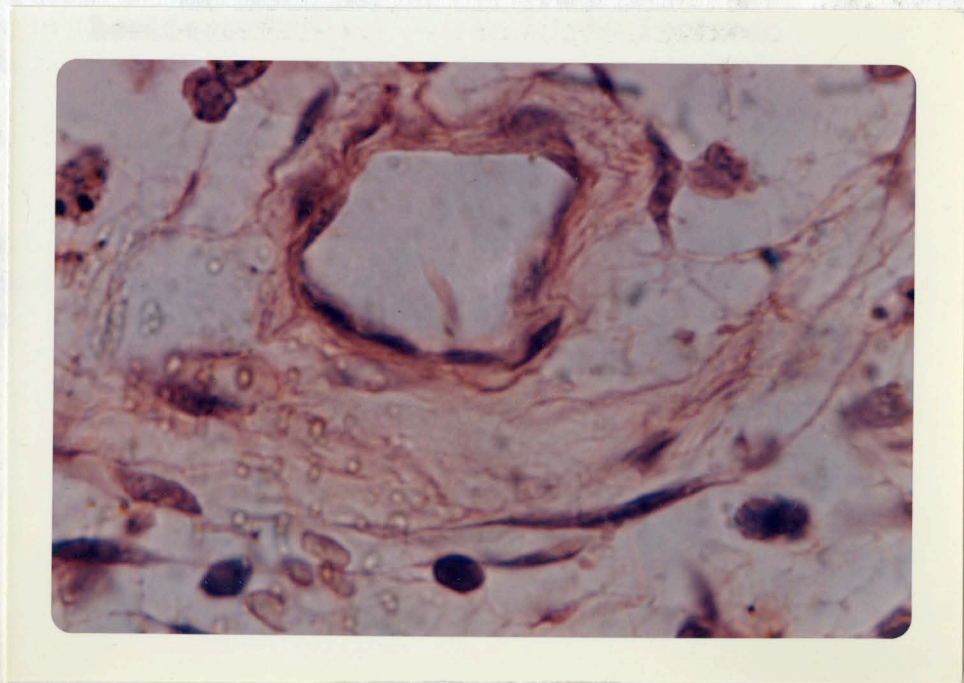


Figure 40

PLATE XXVI

Figure 41. Photomicrograph X 900 nine days eight hour specimen showing young fibroblasts and reserve cells or undifferentiated cells, section through mucoperiosteal flap next to implant.

Note: Fibroblasts with immature collagen fibers.

Figure 42. Photomicrograph X 900 two week specimen showing fibroblasts, histiocytes (macrophages) and reserve cells or indifferntiated cells. Section through mucoperiosteal flap next to implant.

Note: Mature collagenous fibers.

PLATE XXVI

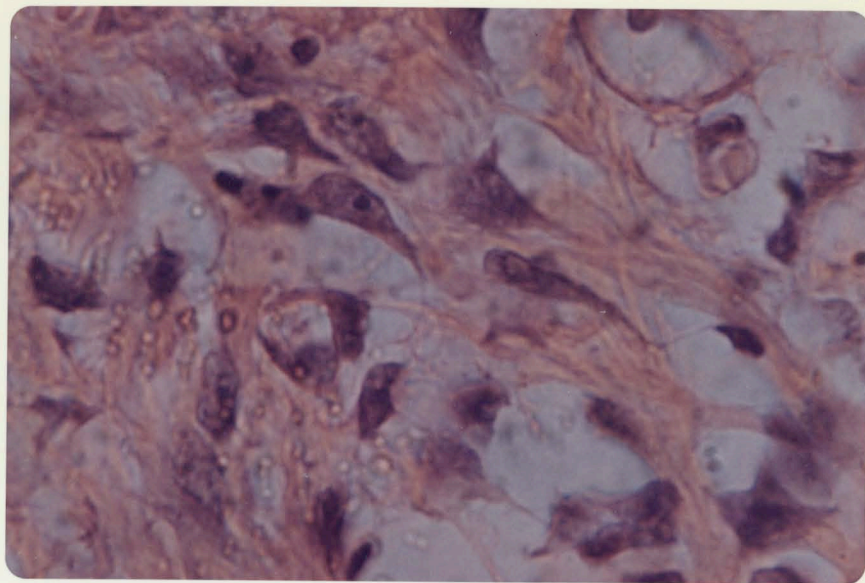


Figure 41

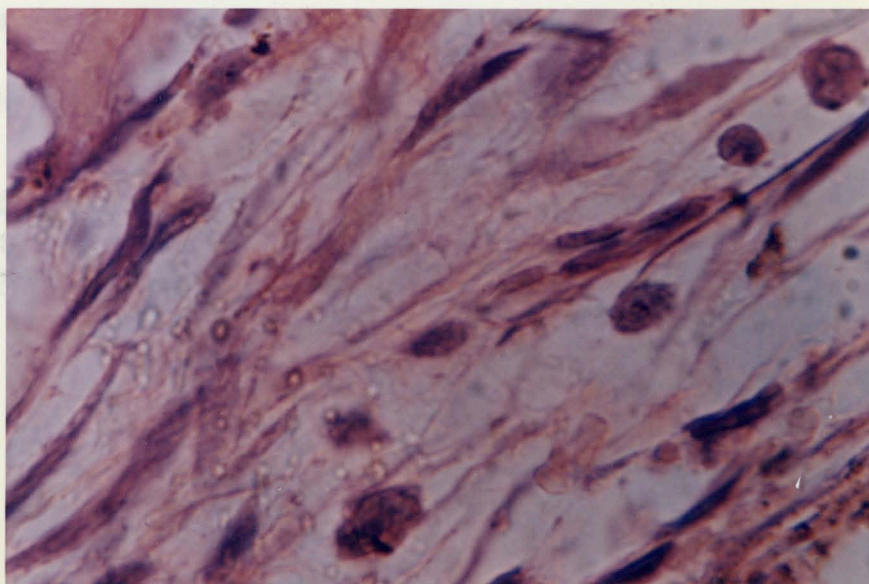


Figure 42

PLATE XXVII

Figure 43. Photomicrograph X 25 one month specimen showing dense fibrous connective tissue capsule encapsulating the metallic implant and separating it from the mandibular canal.

Figure 44. Photomicrograph X 100 of figure 43, section showing dense fibrous connective tissue capsule separating mandibular nerve from metallic implant.

PLATE XXVII

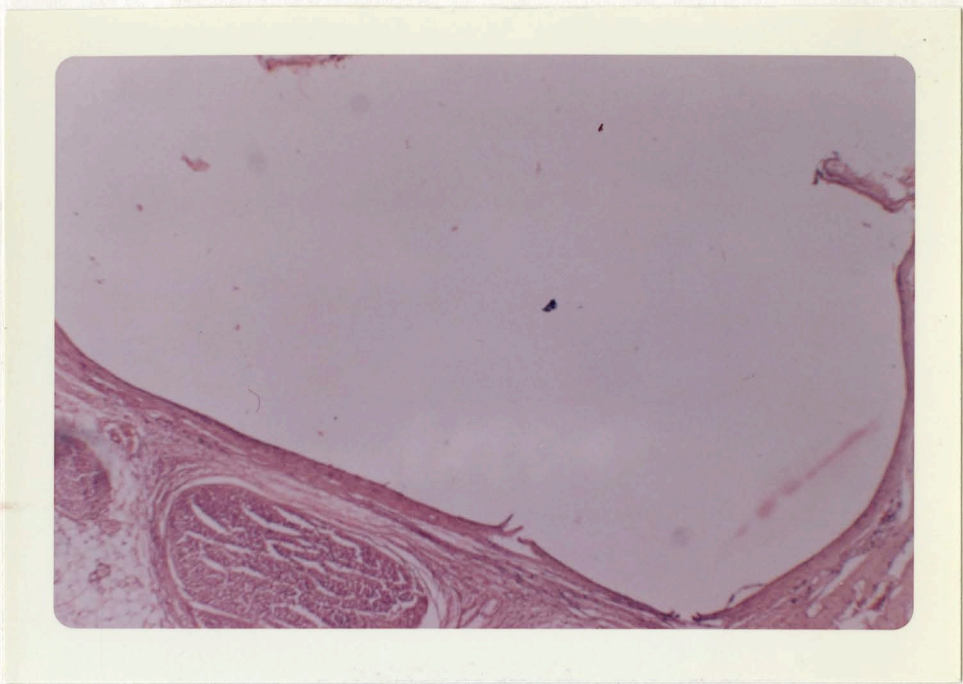


Figure 43

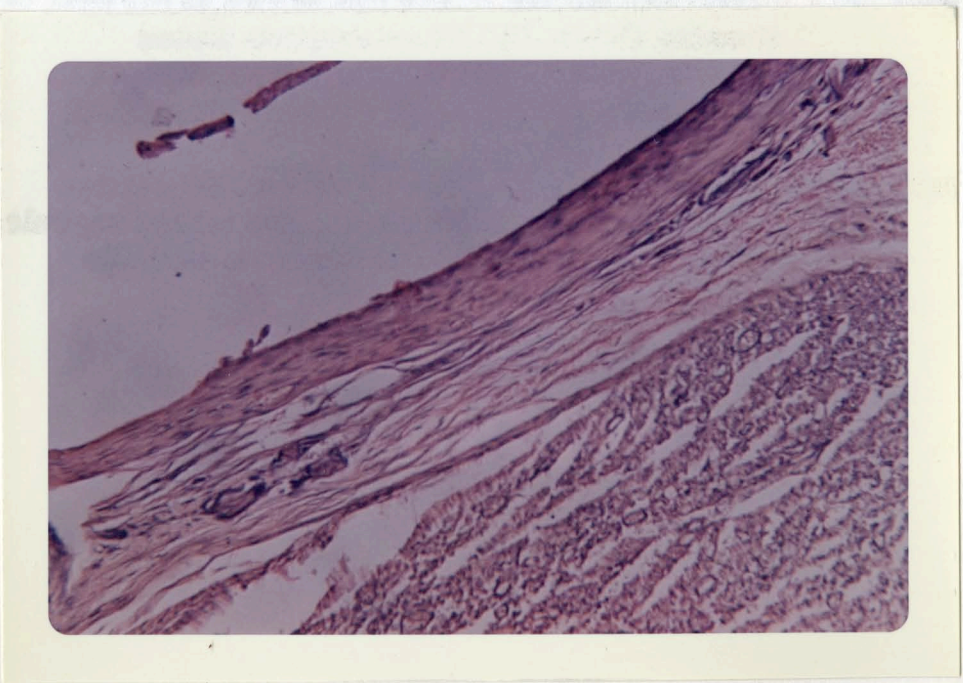


Figure 44

PLATE XXVIII

Figure 45. Photomicrograph X 100 one month specimen, non magnetic implant section showing attachment of fibrous capsule to bone.

Figure 46. Photomicrograph X 100 one month specimen, magnetic implant showing attachment of fibrous capsule to bone.

PLATE XXVIII

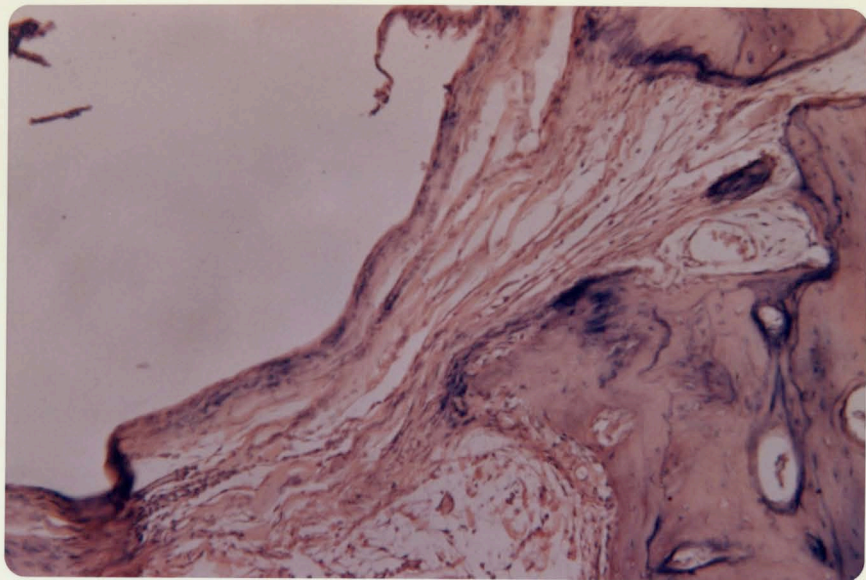


Figure 45

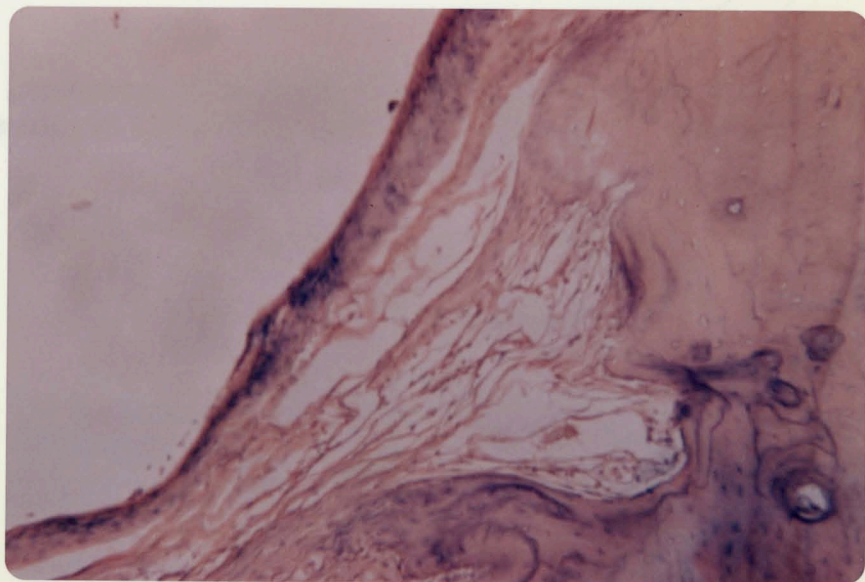


Figure 46

PLATE XXIX

- Figure 57.** Photomicrograph X 400 one month two week specimen showing relationship between dense fibrous connective tissue capsule and bone; capsule serving as a fibrous periosteum on the surface opposing new bone.
- Figure 48.** Photomicrograph X 400 one month two week section through fibrous connective tissue capsule.

PLATE XXIX

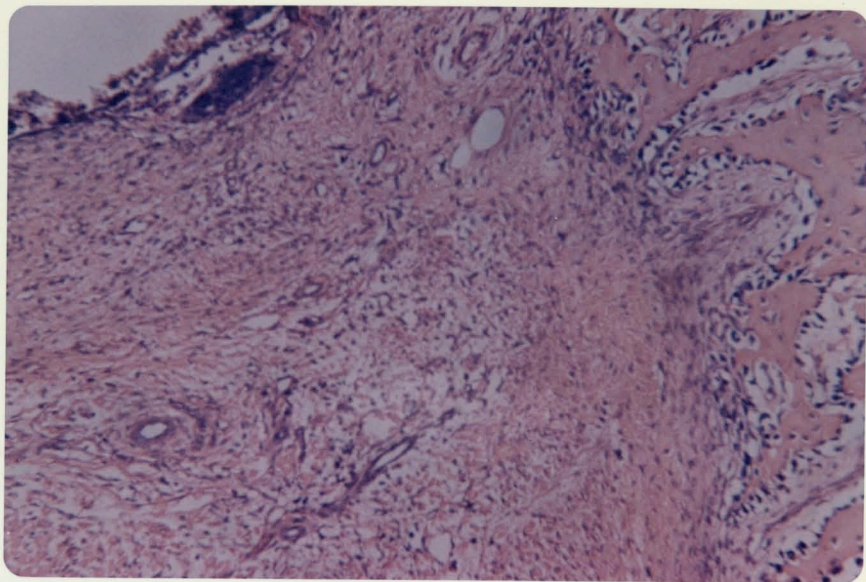


Figure 47

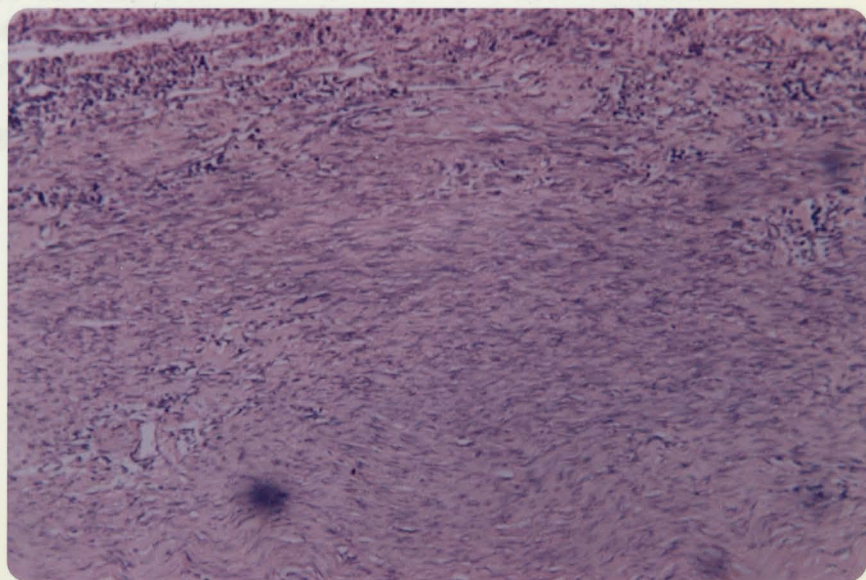


Figure 48

PLATE XXX

Figure 49. Photomicrograph X 25 two months non-magnetic specimen showing reattachment of the mucoperiosteal. The inner surface of the flap is attached firmly to dense fibrous connective tissue which surrounds the empty space created for the metallic implant.

Figure 50. Photomicrograph X 100 of figure 49, two months non-magnetic specimen, section showing mucoperiosteal flap firmly attached to dense fibrous connective tissue.

PLATE XXX

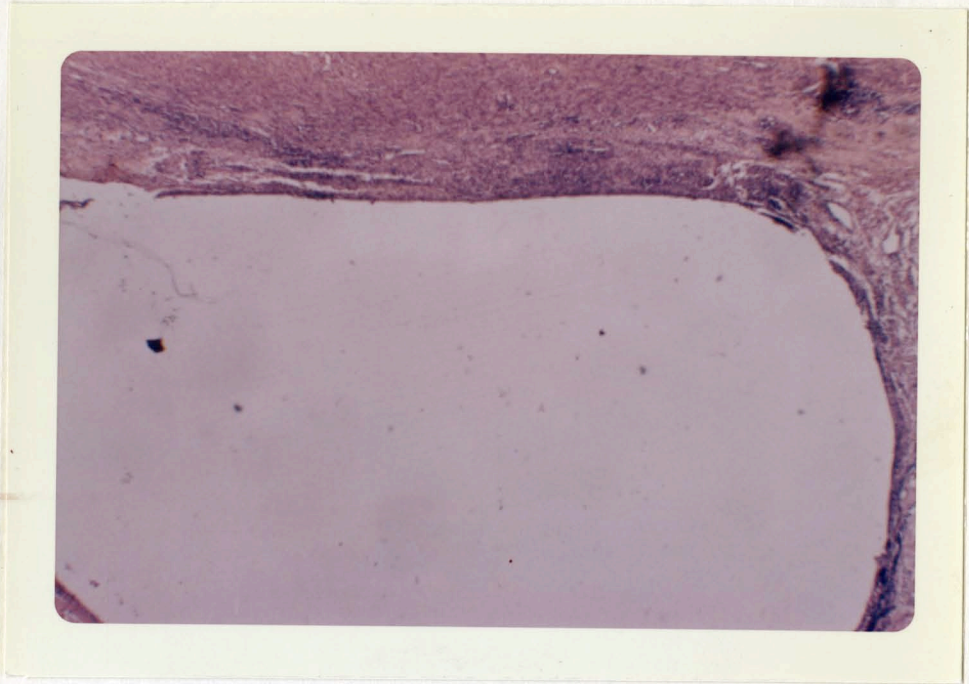


Figure 49

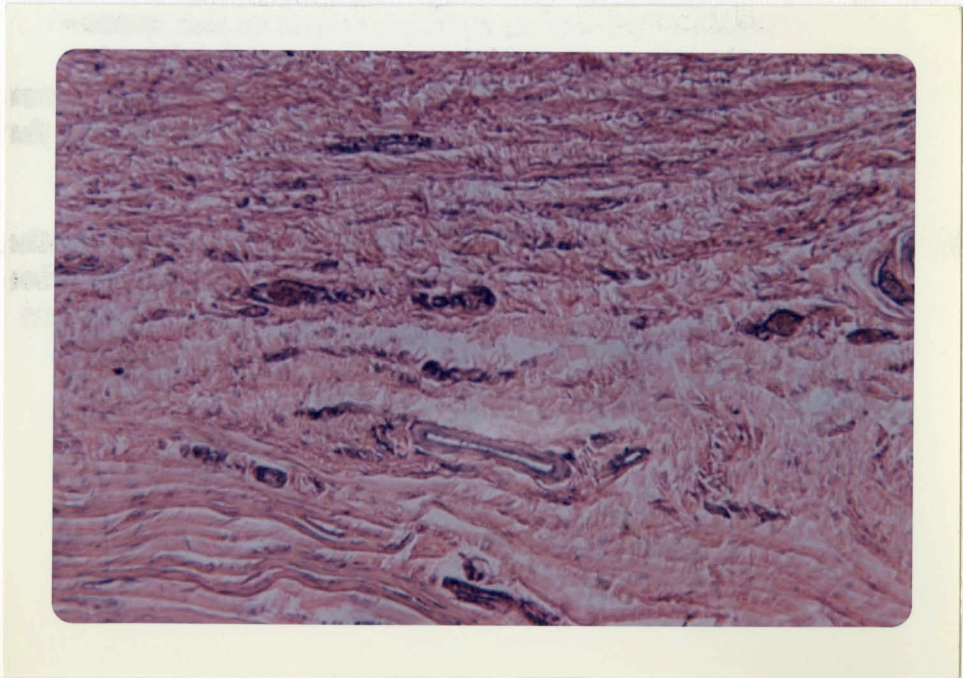


Figure 50

PLATE XXXI

Figure 51. Photomicrograph X 100 one month specimen non magnetic implant showing attachment of fibrous capsule to new bone.

Figure 52. Photomicrograph X 100 two month specimen, magnetic implant showing attachment of fibrous capsule to new bone.

PLATE XXXI

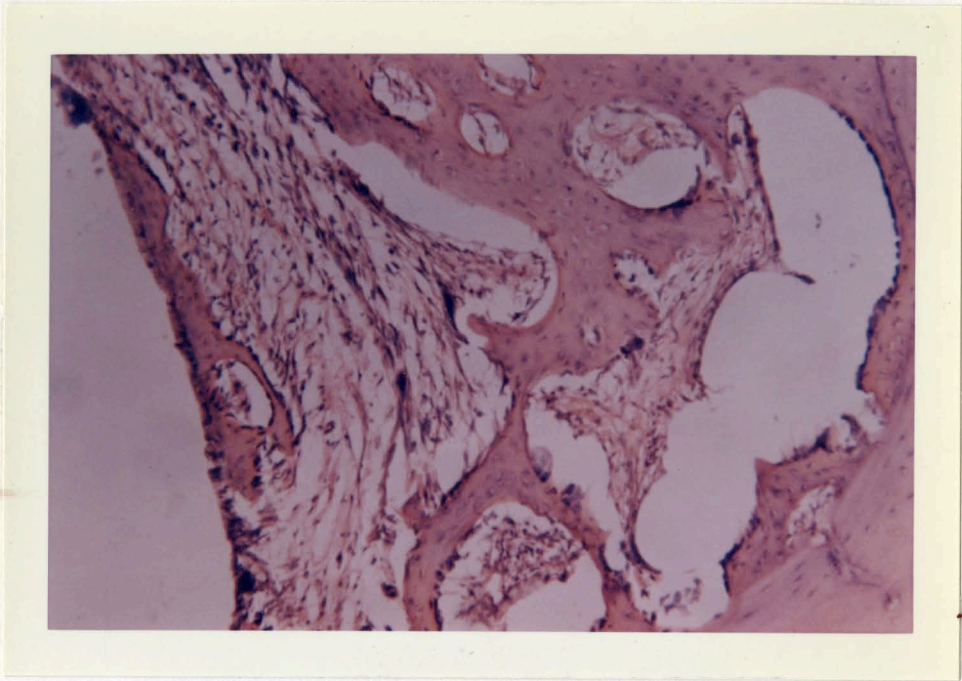


Figure 51

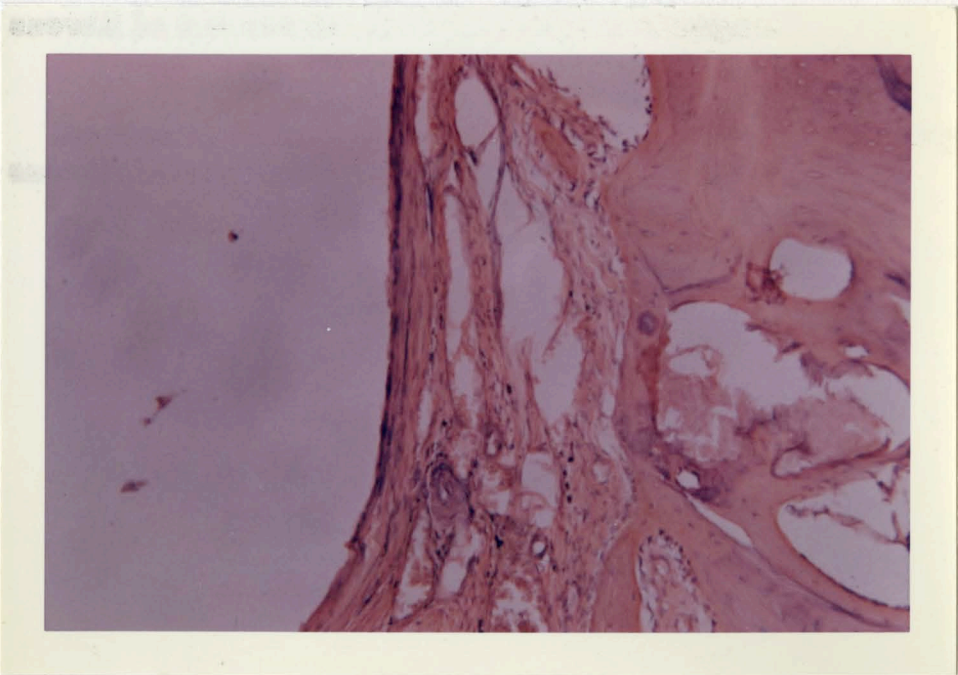


Figure 52

PLATE XXXII

Figure 53. Photomicrograph X 25 three month specimen - non magnetic implant. Section through the base of the bony vault.

Note: (1) The actual intimate contact with the implant is a dense fibrous connective tissue capsule (2) bony bridge which intervenes between the mandibular canal and the fibrous capsule.

Figure 54. High power photomicrograph of figure 53 x 100. Section through peripheral portion of bony vault showing newly formed bone and fibrous connective tissue capsule adoption.

PLATE XXXII

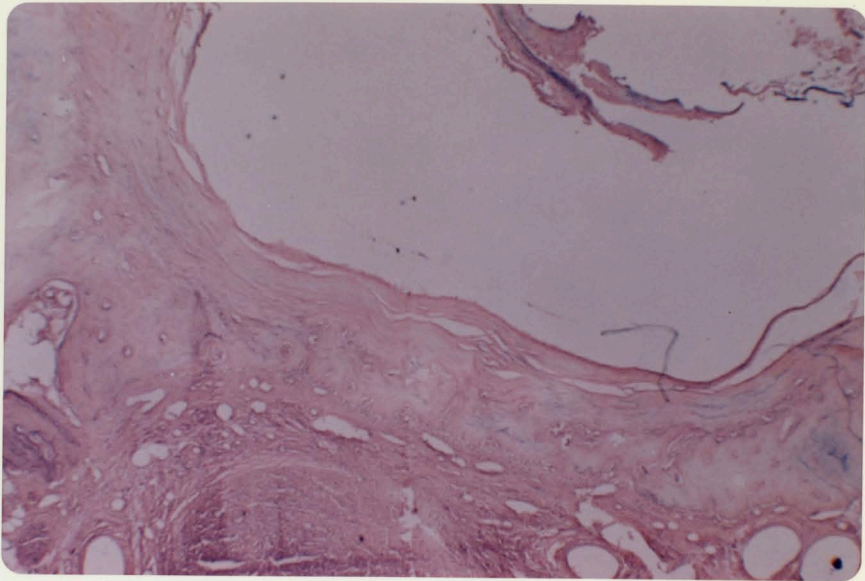


Figure 53

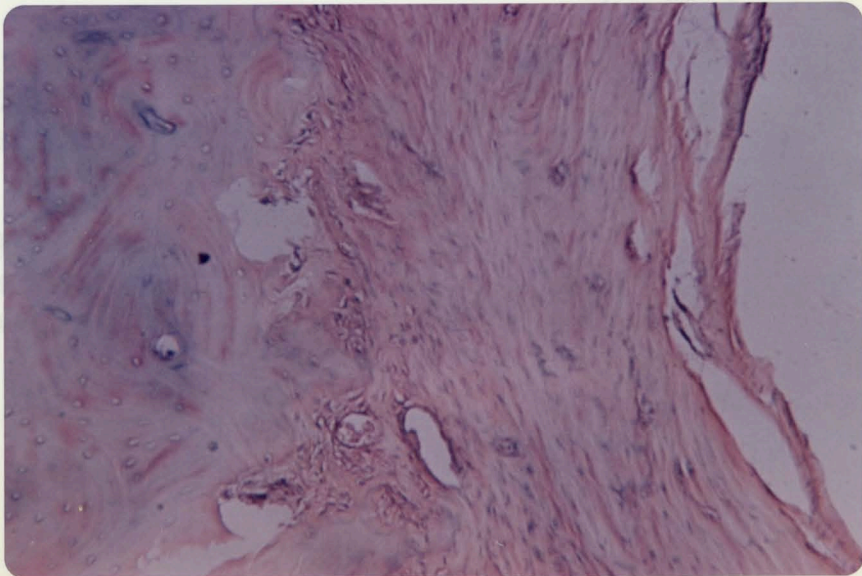


Figure 54

PLATE XXXIII

Figure 55. Photomicrograph X 25 three month specimen - magnetic implant showing mucoperiosteal flap, fibrous connective tissue capsule, and new bony bridge.

Figure 56. High power photomicrograph of figure 55 x 100. Section through fibrous connective tissue capsule, and new bony bridge.

PLATE XXXIII

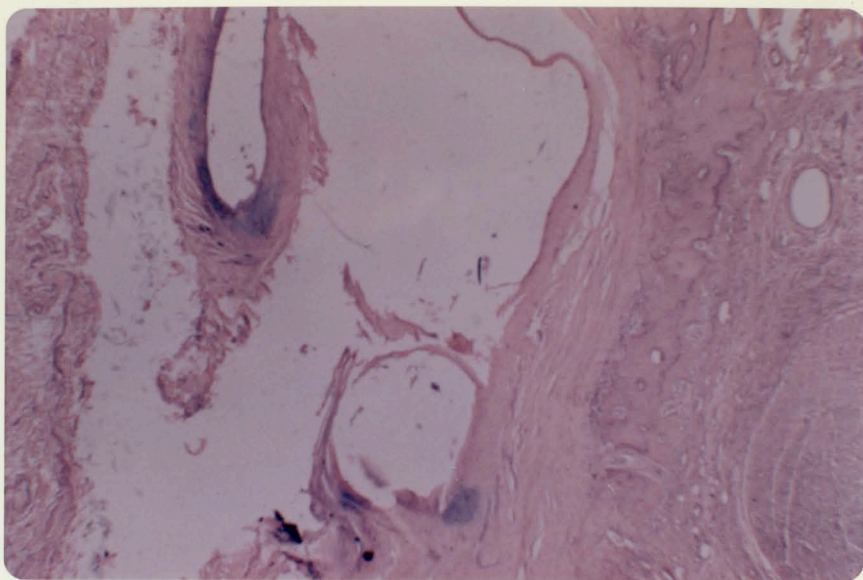


Figure 55

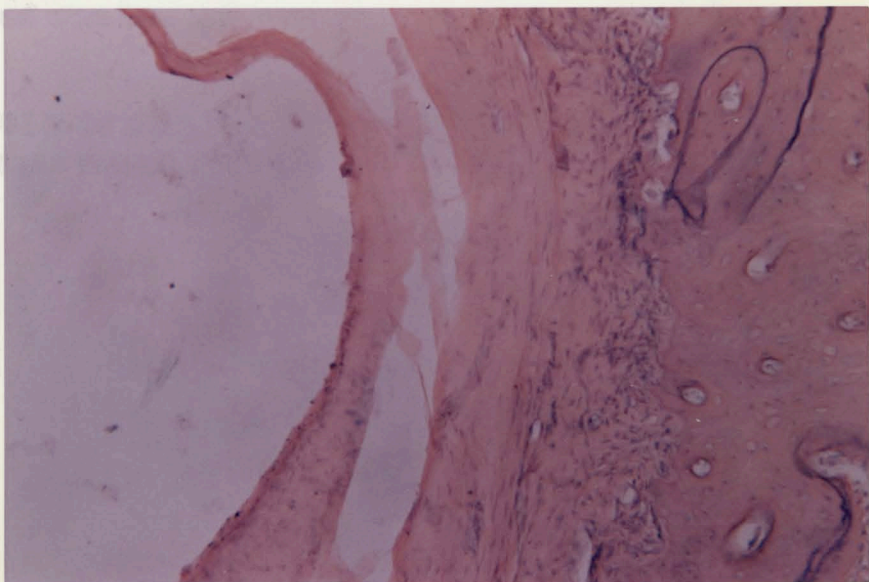


Figure 56

PLATE XXXIV

Figure 57. Photomicrograph X 100 six month specimen magnetic implant section through junction of the dense fibrous connective tissue capsule and bone. The fibrous capsule serves as a fibrous periosteum on the surface opposing bone, and on the other surface it encapsulates the metallic implant.

Figure 58. Photomicrograph X 100 six month specimen non-magnetic implant section through junction of the dense fibrous connective tissue capsule and bone.

Note: Similarity as with six month specimen of magnetic implant.

PLATE XXXIV

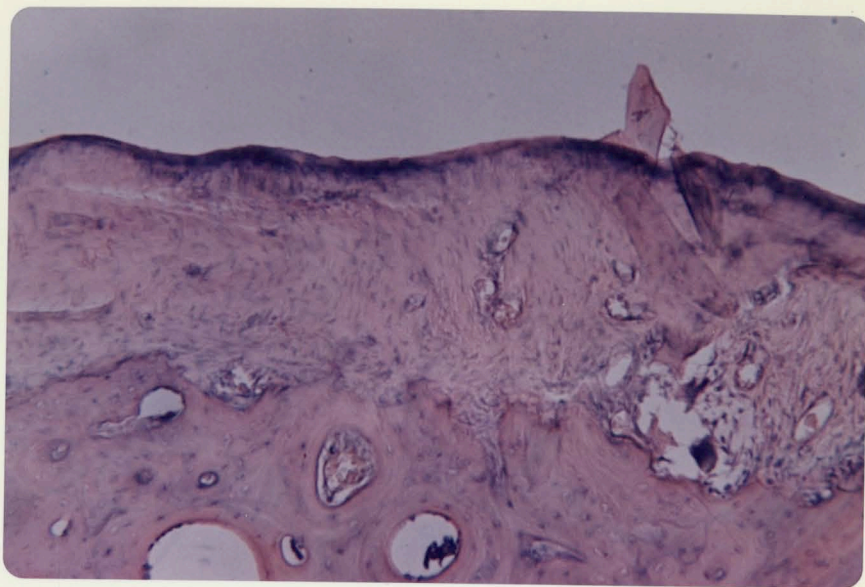


Figure 57

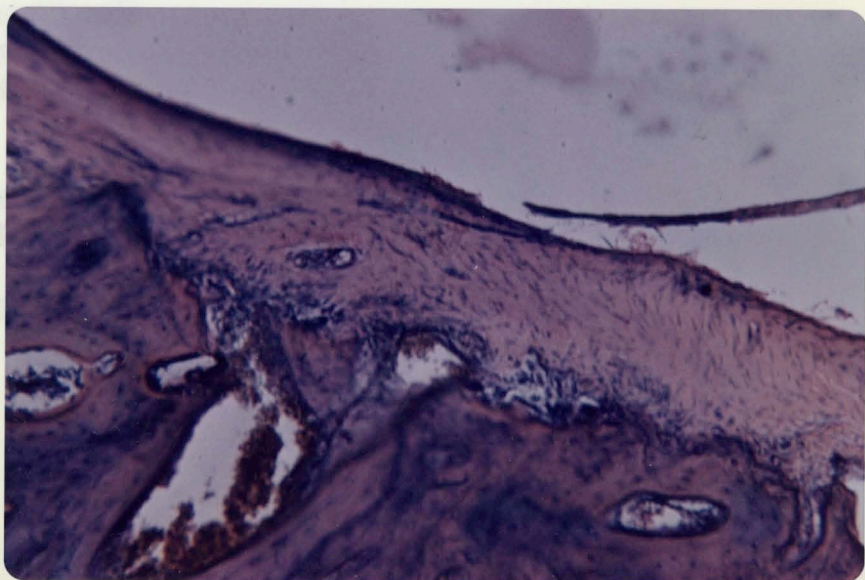


Figure 58

PLATE XXXV

Figure 59. Photomicrograph X 100 six month specimen - non magnetic implant section through fibrous capsule and new bony bridge.

Figure 60. Photomicrograph X 100 of six month specimen - magnetic implant section through mucoperiosteal flap, fibrous connective tissue capsule and bone. Outstanding features of this adaption: (1) The fibrous connective tissue capsule serves a dual purpose; (a) on the surface opposing bone it serves as a fibrous periosteum, as it is a source of osteoclasts and osteoblasts, (b) on the outer surface it encapsulates the metallic implant. (2) The mucoperiosteal flap served as a source of reserve or undifferentiated cells. Note the reversal line.

PLATE XXXV

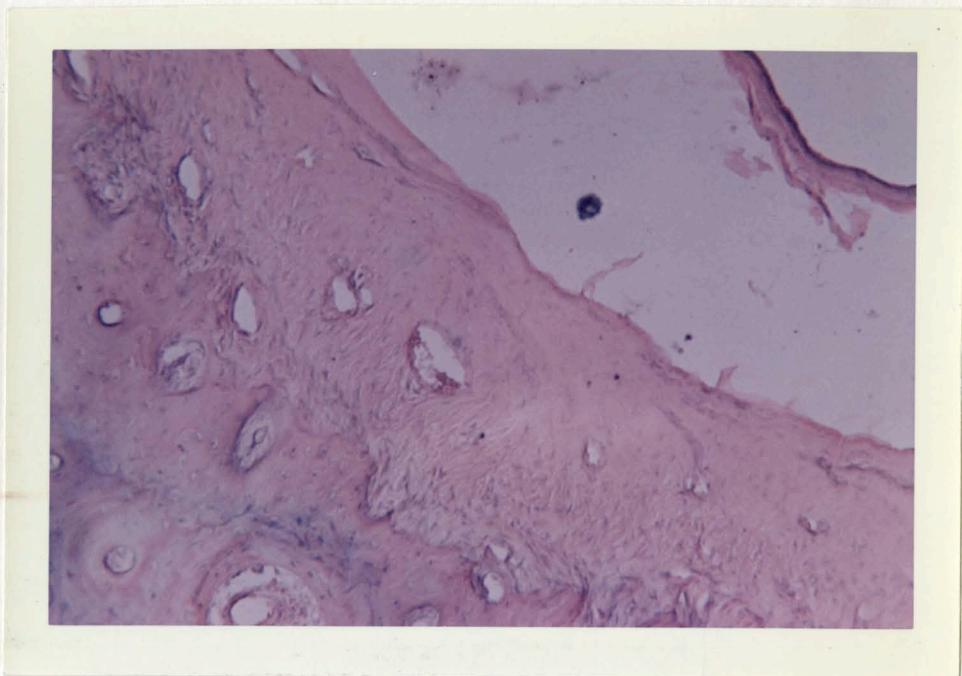


Figure 59

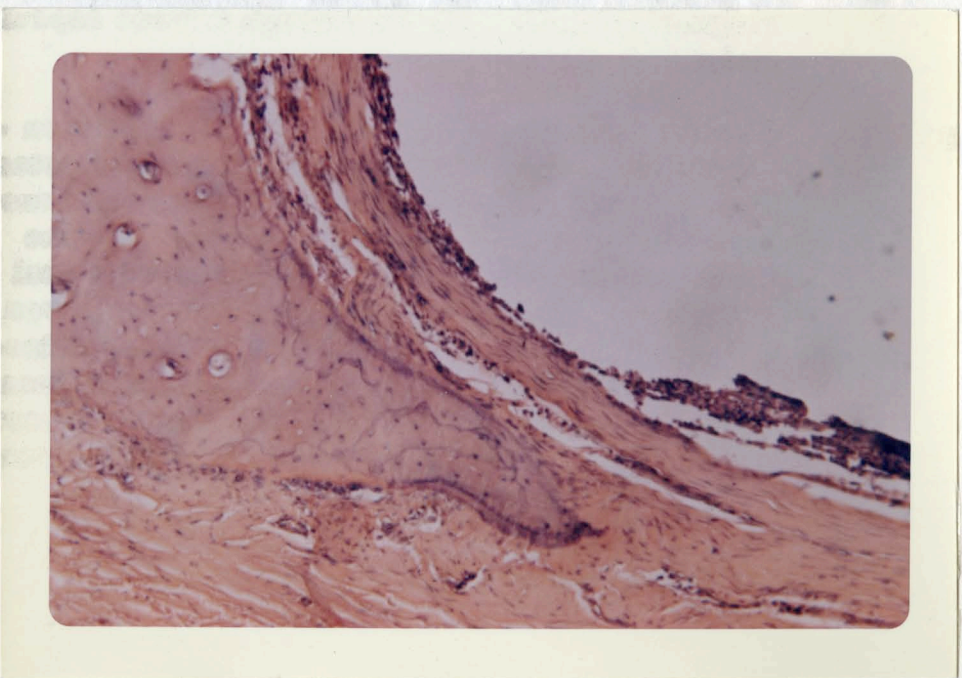


Figure 60

PLATE XXXVI

Figure 61. Photograph of the post operative roentgenogram of Dog No. 1, twenty-four hour specimen; magnetic implant showing site of implantation.

Figure 62. Photograph of the post operative roentgenogram of Dog No. 10, six month specimen, magnetic implant showing site of implantation.

PLATE XXXVI



Figure 61



Figure 62

PLATE XXXVII

- Figure 63. Photograph of the post operative roentgenogram of Dog No. 6, one month specimen; magnetic implant, lateral view.
- Figure 64. Photograph of the post operative roentgenogram of Dog No. 6, one month specimen; magnetic implant, occlusal view.

PLATE XXXVII



Figure 63



Figure 64

PLATE XXXVIII

Figure 65. Photograph of the post operative roentgenograph of Dog No. 2, forty-eight hour specimen; non magnetic implant showing site of implantation, lateral view.

Figure 66. Photograph of the post operative roentgenograph of Dog No. 9, three month specimen; non magnetic implant showing site of implantation, lateral view.

PLATE XXXVIII



Figure 65

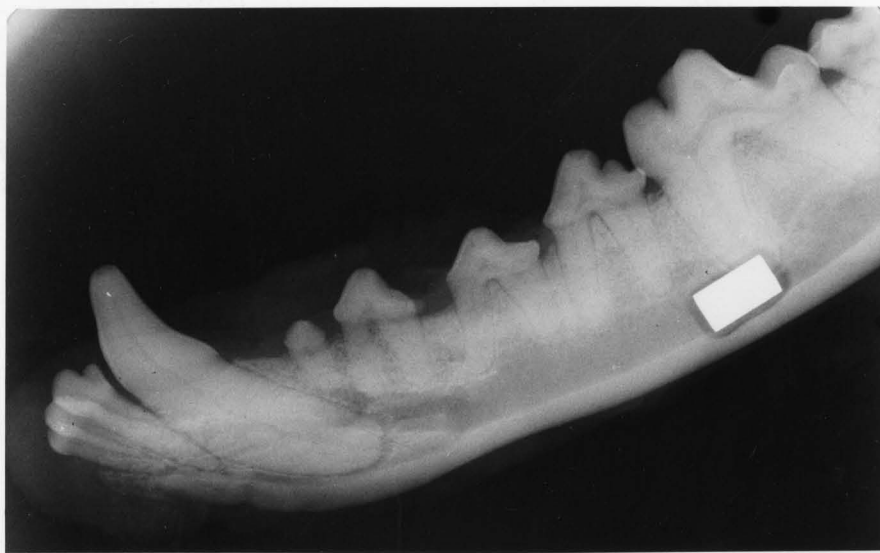


Figure 66

PLATE XXXIX

Figure 67. Photograph of the post operative roentgenogram of Dog No. 8, two month specimen, showing site of implantation of magnetic implant, occlusal view.

PLATE XXXIX

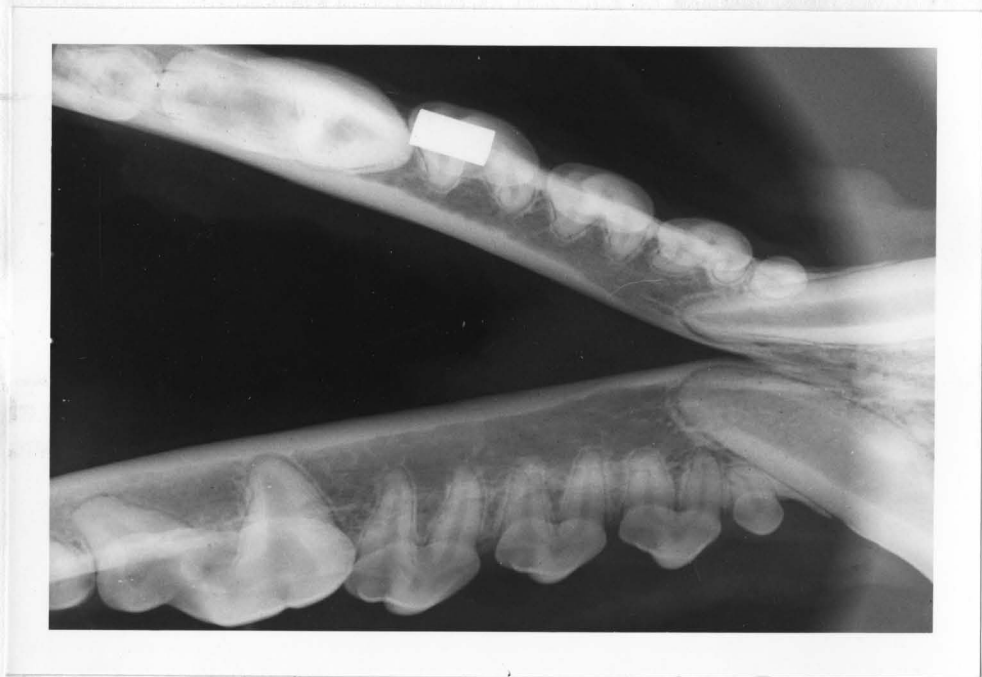


Figure 67

TABLE I

SUMMARY - REVIEW OF THE LITERATURE

Author	Year	Type of Study	Results
Petronius	1565	One of the first men to attempt the closure of a cleft palate with a metal appliance, used a gold plate closure	Not mentioned
Lambotte	1909	Used various surgical prosthesis made of aluminum, silver, brass, red copper, magnesium and soft steel plated with gold or silver (author does not mention type of tissue or site of implantation).	<ol style="list-style-type: none"> 1. "Copper is not well-tolerated by tissues and should be rejected." 2. Steel covered with another metal corrodes much faster than when used on (first recorded statement concerning unfavorable electrolyte and reaction by metal appliance in tissue.)
Hey Groves	1913	Used metal plates and screws in the fixation of fractures; performed 100 experiments, 65 on the tibia and 35 on the femur of 81 cats and 19 rabbits	<ol style="list-style-type: none"> 1. Nickel plated steel did not produce any irritating effects on the tissues. 2. Magnesium produced destruction of bone if in contact only with the cortex
Zierold	1924	Studied the reaction of bone to gold, silver, aluminum, zinc, lead, copper, nickel, high carbon steel and low carbon steel, copper-aluminum alloy, magnesium, iron and	<ol style="list-style-type: none"> 1. Low carbon and high carbon steels produced extensive bone necrosis. 2. Gold, aluminum and stellite, are inert metals, readily tolerated by bone and become encapsulated.

Table I Summary - Review of the Literature (cont.)

Author	Year	Type of Study	Results
Zierold	1924	<p>stellite -</p> <p>Five series of dogs operated on.</p> <p><u>Series I.</u> 15 dogs; middle third of the tibia.</p> <p><u>Series II.</u> 15 dogs: knee joint</p> <p><u>Series III.</u> 4 dogs: Cortex of each tin</p> <p><u>Series IV.</u> 15 dogs: Temporal region of the skull.</p> <p><u>Series V.</u> 4 dogs: Fifth, sixth, seventh, eighth and ninth rib.</p>	<p>3. Silver and lead are easily corroded and evoke a connective tissue response.</p> <p>4. Zinc interferes with bone regeneration; and does not become encapsulated.</p> <p>5. Copper causes stimulation to bone and may be toxic to tissue</p> <p>6. Magnesium retards rather than accelerates bone production</p> <p>7. Steel and iron inhibited bone regeneration</p> <p>8. Steel is poorly tolerated and readily soluble; least suitable of all for bone prosthesis.</p> <p>9. Stellite showed the least departure from normal</p>
Cretin and Ponyanne	1933	<p>Studied the reaction of metal in the medullary cavity of a fractured bone operated upon guinea-pigs and used aluminum, silver, copper, iron, magnesium, nickel, lead and zinc.</p>	<p>All metals excited some degree of destruction which retarded growth of bone, independent of location, whether the metal was placed in the medullary cavity or directly on the bone surface.</p>
Jones and Liberman	1936	<p>Studied the reaction of bone to metal as a foreign body in 5 dogs. Used 4 alloys in the form of tacks: vanadium, high chromium content (nickel-free rustless steel) Nickel absent,</p>	<p>1. The amount of corrosion and ppt. of irritant particles of metal was directly proportional to the magnitude of foreign body reaction of bone</p> <p>2. Chrome-nickel rustless steel was best tolerated</p>

Table I Summary - Review of the Literature (cont.)

Author	Year	Type of Study	Results
Jones and Liberman	1936	low chromium (high nickel rustless steel) content high in nickel, (low nickel rustless steel) high chromium, low in nickel	by bone tissue
Venable, Strock and Beach	1936	Studied the reaction of bone to metals based upon electrolysis as a variable factor. The radiuses of 24 dogs were used. The following metals were used in this group: chromium plated screw, plain steel screw, vanadium steel screw, silver wire, silver-plated steel screw, copper nails, galvanized iron screw, chromium plated steel screw, and vitallium screws. In a subsequent series of dogs, screws of the same metal were placed in duo in bone in different combinations.	<ol style="list-style-type: none"> 1. It is not possible to differentiate accurately the different reactions of 2. An electric force is generated when different metals are placed in tissues. 3. Pure metals are inert 4. It is the electrolytic action which causes the formation of irritating metallic salt solutions in the local fluids. This leads to bone necrosis and foreign body reaction.
Campbell	1939	Reported on the use of vitallium in fractures of bone in humans	Vitallium is a dependable material for the fixation of fractures
Strock	1939	Conducted a study using vitallium screws implanted into the alveols of the jaw bone marrow on two human subjects and on two dogs	Eight months duration in human patients revealed no discomfort except the inconvenience such as accompanies a loose tooth prior to exfoliation. In dogs, after 6 months the

Table I Summary - Review of the Literature (cont.)

Author	Year	Type of Study	Results
Strock	1939		screws were firmly in place.
Cameron and Henderson	1940	Reported on a hundred cases in which vitallium was used for fixation of human fractures	Vitallium showed no evidence of irritation or discoloration to the surrounding bone or soft tissue.
Bothe and Davenport	1941	Did an experiment on the reaction of bone to metal. (No mention is made as to the subject or metal used)	Electrolysis is not the primary cause of unfavorable bone reaction. The primary cause is determined by the physical and chemical properties of the metal itself, the solubility and the degree of toxicity appear to be the chief factors involved.
Geib	1941	Worked with vitallium skull plates	The luster of the metal was unchanged and no adverse tissue reaction was noticeable
Geib	1941	Used tantalum for skull plates	Tantalum is similar to vitallium
Pearce	1941	Reported on two cases, one in a human, the other in a dog, in which a vitallium tube was used as the bite duct	Vitallium was well tolerated
Strock and Ogus	1941 and 1943	Reported on vitallium screw implants in upper anterior sockets	Under mastication stress the implants loosened, when taken out of function they became firm again.
Strock and Strock	1949	Placed a 5/8" vitallium screw in the upper right canine socket of a dog.	At the end of one hundred fifteen weeks a fine layer of connective tissue developed between the implant and the surrounding bone.

Table I Summary - Review of the Literature (cont.)

Author	Year	Type of Study	Results
Herschfus	1955	Histopathologic studies of subperiosteal prosthodontic vitallium implants in 3 and 6 month old dogs.	Implants were retained by periosteal fibers that had proliferated through the meshwork.
Bodine	1955	Reported on subperiosteal mandibular and maxillary premolar implants of ticonium	After one year the implants were held in place by connective tissue
Herschfus	1955	Discussed the implants of vitallium in bone of 14 and 16 months duration in dogs	Fibrous tissue was fused with the periosteum and the interstices of the vitallium meshwork firmly binding the implant
Herschfus	1957	Reported on five year follow-up on a subperiosteal prosthodontic vitallium implant in a dog.	Similar to those reported in the 3, 6, 9, 14 and 16 month old dogs.
Gross and Gold	1957	Conducted an experiment on the compatibility of of cast-vitallium, wrought vitallium, and austanium screws and plates for surgical use.	Cast-vitallium and austanium plates and screws, combined or separated, were compatible with the soft tissues and bone.
Cobb	1960	Mechanically secured two oral vitallium implants subperiosteally in the premolar area of the maxillary alveolar process of two dogs following extractions.	At the end of three months period no notable reaction of bone from pressure brought to bear by a vitallium implant mechanically secured, and no foreign body reaction of the soft tissues or bone.
Behrman	1960	Reported on the tissue tolerability of metallic implants in both dogs and humans. Four types of material were im-	Each implant appeared to be surrounded by a thin, fibrous tissue capsule.

Table I Summary - Review of the Literature (cont.)

Author	Year	Type of Study	Results
Behrman	1960	planted; subperiosteal material, were cast vitallium mesh frames and squares of tantalum mesh. Intrabony implants were two alnico V magnets; one coated with methyl methacrylate and the other was not	
Behrman	1960	Implanted platinum cobalt alloy magnets in the body of the human mandible	After six months duration the magnets were held firmly in place by bony growth around the edges of the implant

TABLE II

Anesthetic - Sodium Pentobarbital (Nembutal, Abbot) 5% Sol.

Spec. No.	Time of Administration	Route of Administration	Dosage	Stage of Surgical Anesthesia	Duration of Anesthesia
Dog No. 1 24 hrs.	8 A. M.	Intra- Peritoneal	4 c. c.	10 min.	4 1/2 hrs.
Dog No. 2 48 hrs.	8:10 A. M.	"	4.5 c. c.	23 min.	4 hrs.
Dog No. 3 72 hrs.	8 A. M.	"	5 c. c.	12 min.	4 hrs.
Dog No. 4 9 days 8 hrs.	8 A. M.	"	4.5 c. c.	20 min.	4 1/2 hrs.
Dog No. 5 2 weeks	8 A. M.	"	4 c. c.	20 min.	4 hrs.
Dog No. 6 1 month	8 A. M.	"	4.5 c. c.	10 min.	4 hrs. 15 min.
Dog No. 7 1 month 2 weeks	8 A. M.	"	5 c. c. Stat. 1.5 c. c. 1/2 hr. later	14 min.	5 hrs.

Table II (cont.)

Anesthetic - Sodium Pentobarbital (Nembutal, Abbot) 5% Sol.

Spec. No.	Time of Administration	Route of Administration	Dosage	Stage of Surgical Anesthesia	Duration of Anesthesia
Dog No. 8 2 months	8 A. M.	Intra- Peritoneal	6 c. c. Stat. 1 c. c. 1/2 hr. later	10 min.	5 1/2 hrs.
Dog No. 9 3 months	9:30 A. M.	"	5 c. c.	15 min.	4 hrs.
Dog No. 10 6 months	8 A. M.	"	4 c. c.	13 min.	4 hrs.

REMARKS (1) Stage of surgical anesthesia reached in approximately 15 minutes (average).
(2) Duration of anesthesia - approximately 4.4 hrs. (average).

TABLE III

SURGERY

Spec. No.	Date of Surgery	Operative Procedure	Comments on the Surgery	Duration of Operation
Dog No. 1 24 hrs.	June 27, 1960	Normal flap design: Gingiva reflected down from the crest of the alveolar	Animal withstood both the surgical procedure and anesthesia nicely Bi lateral implants,	45 min.
Dog No. 2 48 hrs.	July 29, 1960	See Methods & Materials	Magnetic and non-magnetic implant Animal withstood both the surgical procedure and anesthesia nicely	30 min.
Dog No. 3 72 hrs.	June 28, 1960		Mandibular artery was cut during surgery; approx. 10 min. to control bleeding with press packs	45 min.
Dog No. 4 9 days 8 hrs.	June 12, 1960		Animal withstood both the surgical procedure and the anesthesia nicely	20 min.
Dog No. 5 2 weeks	June 28, 1960	Reverse flap design; incision made in	Bi lateral implants magnetic and non-magnetic implants	30 min.
Dog No. 6 1 month	July 1, 1960	buccal sulcus and gingiva was reflected	Additional 1.5 c. c. of anesthetic required 1/2 hr. later to control animal.	1 hr.
Dog No. 7 1 month 2 weeks	Sept. 1, 1960	upward toward the		

Table III (cont.)

SURGERY

Spec. No.	Date of Surgery	Operative Procedure	Comments on the Surgery	Duration of Operation
Dog No. 8 2 months	July 22, 1960	crest of the alveolar process.	Additional 1 c. c. of anesthetic required 1/2 hr. later to control animal	45 min.
Dog No. 9 3 months	July 23, 1960	See Methods and Materials	Bi lateral implants magnetic and non-magnetic implants	35 min.
Dog No. 10 6 months	June 24, 1960	Materials	Bi lateral implants magnetic and non-magnetic implants	35 min.

REMARKS

- (1) The preparation of the vault extended through the cortex, the marrow and into and involving the mandibular canal and its content; the mandibular nerve, artery, and vein.
- (2) The mandibular canal runs at the level of the apices of the mandibular fourth premolar and first molar.
- (3) Dog Nos. 2, 6, 9, 10 possess bi lateral implants. Magnetic on left side; non-magnetic on right side.

TABLE IV

WEIGHT AND PROGRESS

Spec. No.	Weight of Animals		Diet	Daily progress	Date of Sacrifice
	Pre-Operat.	Post-Operat.			
Dog No. 1 24 hrs.	19 lbs.	18 lbs.	Soft diet day of	Normal	June 28, 1960 11 A. M.
Dog No. 2 48 hrs.	20 lbs.	18 lbs.	surgery followed by standard hospital	Unsatisfactory	Died July 31, 1960 Pneumonia
Dog No. 3 72 hrs.	25 lbs.	23 lbs.	dog rations: - Mixture of Purina	Normal	July 1, 1960 9 A. M.
Dog No. 4 9 days 8 hrs.	17 lbs.	16 lbs.	Dog kibbled Meal (1 Part), Miller's	Normal till 8th day - stops eating	June 30, 1960 5 P. M.
Dog No. 5 2 weeks	20 lbs.	17 lbs.	Puppy Meal (2 Parts)	Normal	July 12, 1960 8 A. M.
Dog No. 6 1 month	20 lbs.	15 lbs.	and freshly ground	Normal	July 30, 1960 8 A. M.

Table IV (cont.)

WEIGHT AND PROGRESS

Spec. No.	Weight of Animals		Diet	Daily progress	Date of Sacrifice
	Pre-Operat.	Post-Operat.			
Dog No. 7			horse meat (1 part)		Died
1 month					Oct. 14, 1960
2 weeks	24 lbs.	20 lbs.		Unsatisfactory	2:30 P. M. Pneumonia
Dog No. 8					Sept.
2 months	30 lbs.	24 lbs.		Normal	23, 1960
Dog No. 9					Oct.
3 months	22 lbs.	10 lbs.		Normal	22, 1960 8 A. M.
Dog No. 10					Dec.
6 months	19 lbs.	16 lbs.		Normal	22, 1960 10 A. M.

REMARKS

(1) Of the ten dogs operated upon an average net weight loss of 3.8 lbs. was noted.

(2) Dogs Nos: 1 and 7; autopsy performed; microscopic section of lung revealed cause of death to be pneumonia.

(3) Dog No. 2 stopped eating on the eighth day and was sacrificed at 9 days 8 hours. (Autopsy performed - revealed pneumonia.)

TABLE V

APPROXIMATE AGE OF ANIMALS

<u>Animal Number</u>	<u>Sex</u>	<u>Age of Animal (in years)</u>
1	Female	1 1/2
2	Female	2
3	Male	2 1/2
4	Female	2
5	Male	3
6	Female	2
7	Male	2 1/2
8	Female	2
9	Male	2 1/2
10	Female	3

- Remarks:
- (1) Age determination is based mainly on the characteristics of the incisors and canines.
 - (2) At one year the teeth are fresh, white and whole.
 - (3) At fifteen months the lower incisors start to show some wear.
 - (4) Between eighteen months and two years the cusps on the lower incisors finally disappear.
 - (5) Between two and a half and three years cusps on the lower intermediates disappear; those on the upper incisors show some wear.
 - (6) At four years the cusps on the upper incisors disappear and the intermediates start to flatten out. The teeth begin to get yellow and calculus deposits are often observed at the base of the canines.
 - (7) At five years all the incisors are markedly worn; toward the sixth year the canines get greenish and mossy.

Table V Approximate Age of Animals (cont.)

- (8) The age can still be determined by the degree of wear of the teeth, the accentuation of their darker color, their gradual loss or removal and several other signs furnished by the hair and skin. In most dark haired dogs gray hairs appear under the lips and around the nose.

APPROVAL SHEET

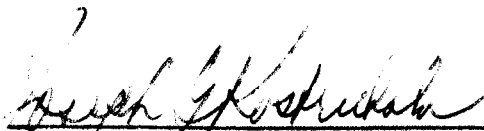
The thesis submitted by Anthony V. Abati has been read and approved by four members of the faculty of the Graduate School.

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 thesis is now given final approval with reference to content, form and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

Date

May 24 1961



Signature of Adviser

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