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A Clinical and Histologic Study of the Effects and Retention of a Pair of Magnetic Metal Implants in the Jaw

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A CLINICAL AND HISTOLOGIC STUDY OF THE EFFECTS AND RETENTION OF A PAIR OF MAGNETIC METAL IMPLANTS IN THE JAW

by

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LIFE

Daniel D. Sanders was born in Chicago, Illinois, June 7, 1936.

From 1954 to 1956 he attended Northwestern University, Evanston, Illinois, in the pre-dental curriculum. In September, 1956, 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 1960.

In September, 1960, he began a two year graduate program at Loyola University leading to a Master of Science Degree in Oral Biology.

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TABLE OF CONTENTS

CHAPTER I

INTRODUCTION

The dental profession has long been trying to devise satisfactory methods of maintaining denture stability during mastication and the normal movements of the mouth.

The purpose of this thesis is to investigate the feasibility of the implantation of a pair of attracting platinum-cobalt magnets in oral prosthesis. The findings are presented in order to demonstrate the reaction of the hard and soft tissues in the jaw and the retention characteristics of an implant magnet. In presenting this information, the author does not wish to imply that the use of magnets can compensate for a faulty technique, but rather that it will serve as an adjunct to help the edentulous patient who is unable to, or will not, tolerate the conventional denture.

CHAPTER II

REVIEW OF THE LITERATURE

A. The Use of Magnets in Dentures

The use of magnets to aid in denture retention and stability is not a recent technique. Prior to the development of magnetic implants, repelling magnets were in use which, when placed opposite each other in the upper and lower denture, were to maintain the denture during movements of the mouth. The theory was that the repelling force of the magnets would act to keep the dentures firmly seated as the upper and lower jaws were brought together. This seemed to be an answer to the existing challenges which were presented by the difficult prosthetic patient. However, use of this technique demonstrated that it too had its limitations. Berman (1953) said that when using repelling magnets, "the stability of the prosthesis will depend a great deal on the amount of the alveolar process especially in lower dentures". This meant that the patient who needed the most help, one with little or no existing alveolar ridge, once again became an unfavorable candidate for a full lower denture. Freedman (1953) reported that direct opposition of these magnets can cause the lower denture to be pushed out of the mouth. Certainly such a position

must be attained at some time during the chewing and speaking movements of the mandible. Grimaldi (1954) pointed out that over a period of time these magnets will weaken, necessitating recharging and that there were certain limitations as to the type of teeth used when constructing such dentures. He said that plastic posterior teeth must be used which are anatomic in form. Here again, because of these limitations, certain patients fall into the group of unfavorable denture candidates.

In the year 1953, a report by Behrman and Egan reanimated the concept of the use of a pair of magnets to aid in denture retention. Their idea was to use a pair of attracting magnets; implanting one into the jaw while its mate was placed in the denture. Since earlier experiments in implantodontics had shown that bone resorption was directly proportionate to implant mobility, they decided to use an implant magnet that would fit solidly in bone and be completely covered by tissue.

In their early experiments conducted in 1949, they implanted alnico V magnets, coated with methyl methacrylate into the mandible of dogs. When the animals were sacrificed, there was no evidence of irritation of bone or soft tissue. Each implant appeared to be surrounded by a thin, fibrous tissue capsule.

Following the animal experiments, a clinical trial was attempted

with the alnico V magnets. From this trial it was concluded that alnico V magnets strong enough to aid denture retention would be too large to be implanted in resorbed mandibles.

Behrman (1960) reported that in December of 1951 it was learned that a very powerful magnetic alloy of platinum and cobalt could be obtained. In April 1952, platinum-cobalt magnets were implanted into an early trial patient. After eight months of observation, there were no gross deleterious changes in the mucosa overlying the implant and roentgenographically bone appeared to fill in any areas of surgical defect.

Once again animal experiments on dogs were undertaken to determine the tissue tolerability to the new platinum-cobalt alloy. Two platinum-cobalt magnets were used, one was coated with polytetrafluoroethylene and the other was left uncoated. After ten weeks the implants were removed and histopathologic examination showed excellent tissue toleration of both the uncoated and coated implants.

In 1960 Behrman reported on eleven cases where he had implanted platinum-cobalt magnets in humans. The patients had been using these magnets for a period ranging from four to eight years. The results of these patients were:

1. Five cases were excellent.
2. Two cases were good.
3. One case was fair. The magnet had rotated after insertion.
4. Two cases were poor. One patient had no primary healing and poor health precluded further trial. The other patient had defective magnets which were removed.
5. One case was incomplete. This was a demonstration case and the implants were pulled out immediately after the surgical operation. The physical condition of the patient did not permit replacement of the magnets.

Abati (1961) undertook a study to determine tissue reaction to a single, non-attracting magnetic metal implant. He introduced a series of magnetic and non-magnetic platinum-cobalt implants into the mandible of ten dogs. The animals were sacrificed at intervals ranging from twenty-four hours to six months. His findings were that the metallic implant composed of the platinum-cobalt alloy was inert, the metal merely occupying space and in no way affecting the regeneration

of bone. There was a complete absence of foreign body giant cells and the entire reaction was a connective tissue response of normal healing. 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.

Review of the literature has failed to reveal any work where a detailed histological study was made when two attracting platinum-cobalt magnets are used to aid in denture retention. This investigation is being undertaken to present this information so that the feasibility of magnetic metal implants in oral prosthesis can be better evaluated.

B. The Metals: Platinum, Cobalt, and their Alloy

Platinum is a chemical element occurring as a metal and found as small grains or nuggets in ore deposits along with osmium and iridium. Its chemical symbol is Pt while its atomic number is 78 and its atomic weight is 195.23. This metal has a density of 21.45 and a melting point of 1770°C. Platinum is soluble in aqua regia, insoluble in hot nitric acid, and shows no reaction with oxygen. Due to its high melting point, incorrodability, and malleability, platinum is almost indispensable in the manufacture of chemical utensils and electrical products.

Review of the literature reveals that very little is said about the use of platinum in implant surgery. Muldoon, Ripple, and Wilder (1951) placed pure platinum implants in various areas of the eyes of rabbits. Their findings were:

> clinically the rabbit eyes showed little or no reaction to platinum implants during a period of observation of from five to seven months. Pathologic examination revealed in all cases there was only a slight foreign body reaction around the wire and no evidence of intraocular inflammation, except in that of the cyclodialysis implant. The rather severe pathologic changes noted when the implant was placed in contact with the ciliary body seems to indicate that the region is an unfavorable site for any implant of any kind.

Cobalt (chemical symbol Co) is a metal which has an atomic weight of 58.69 and an atomic number of 28. The density of cobalt is 8.9 and it has a melting point of 1452°C. Cast cobalt has a tensile strength of 35,000 pounds per square inch. Cobalt is one of the constituents of the alloy alnico, containing aluminum, nickel and cobalt, which was used to make the early permanent magnets for denture implants. Cobalt is strongly magnetic and its transition temperature, magnetic to non-magnetic form, is 1150°C.

Works of several authors seem to indicate that pure cobalt is poorly tolerated by body tissues. Heath (1954) reported on the carcino-

genic qualities of cobalt. In 1960, he studied the histogenesis of malignant tumors which were induced in rats by injecting them with cobalt metal powder.

Pirila (1953) reported on sensitization to cobalt seen in pottery workers; and Schwartz, Peck, Blair, and Markuson (1945) conducted patch tests and were able to show that sensitivity to metallic cobalt was the cause of an allergic dermatitis.

Harding (1950) concluded that "cobalt metal powder suspended in saline or in air produces severe acute damage to capillaries." He said that the action of cobalt is related to its solubility in protein-containing fluids. It is 500 times more soluble in plasma than in saline.

Cobalt has been combined with other metals and these alloys have been used quite extensively in medicine and dentistry without producing any adverse effects.

An alloy developed in 1936, composed of 77% platinum and 23% cobalt is available commercially. This metal is prepared by cold rolling and the finished product has a density of 11gr./$cm.^3$ and possesses the properties of malleability and ductility. This alloy is the metal used in the magnetic implants which were developed by Behrman and later

studied by Abati. Abati (1961) implanted this alloy into the mandibles of dogs and found that this metal was inert and produced no foreign body reaction over a six month period.

C. Magnetism

1. General Description

It was known to the ancients that certain iron ores had the power of attracting iron filings and small fragments of the same ore. The first specimens of this ore were obtained at Magnesia in Asia Minor and were therefore known as magnets.

A piece of steel or iron is conceived as made up of particles each one of which is a little magnet. When the steel is not magnetized these particles are thought of as disorganized and pointing in all directions under the molecular forces and thermal agitation. Such a bar shows no evidence of poles, and we say it is not magnetized.

If, however, the bar of steel is placed between the poles of a powerful magnet, the particles of the bar are re-arranged, being drawn apart from their former association under the influence of the more powerful external attraction. The particles are now arranged in continuous chains or filaments, running from one end of the magnet

toward the other. If two magnets were now brought near each other, it would be seen that the like poles repel and the unlike poles would attract each other.

If a magnet is broken in the middle, it will be found that poles have appeared where it was broken and that each fragment has two opposite poles. However small the magnet may be broken up, each piece shows a north pole and a south pole. No one has ever made a magnet with one pole. The fact that fragments of a magnet always have two poles indicates that magnetism is a condition which prevails throughout the whole mass of the magnet, and polarity is merely an external manifestation of that condition.

The law of force between two magnets was first carefully studied by Coulomb (1736-1806). By his investigation Coulomb was led to enunciate the law that the force between two magnet poles is proportional to the strength of the poles and inversely proportional to the square of the distance between them. The law may be represented algebraically thus:

$$F = \frac{m \ m'}{r^2}$$

where F represents the force, m and m' the strengths of the two poles,

and r the distance between them.

A unit pole, or a pole having unit strength, is one which if placed one centimeter from an equal pole in a vacuum will repel it with a force of one dyne.

The region around a magnet is said to be a magnetic field of force. This field may be demonstrated by laying a sheet of glass on a magnet and dusting fine iron filings over it. On gently tapping the plate, the filings gather into lines or filaments indicating the direction of the magnetic force in the field. The magnetic field strength may be defined in terms of magnetic poles. At one centimeter from a unit pole the field strength is one "oersted".

2. Platinum-Cobalt Magnets

The platinum-cobalt magnets used in this investigation are the same ones which were used by Behrman and later by Abati. It was found that this alloy had the highest energy product of any of the alloys with noble metals.

Magnetism is best retained when the alloy is heat treated by quenching in oil or water at 1200°C and then aging it at 650°C. According to Behrman (1960) these magnets are considered "lifetime" rather than "permanent" because when used as an implant, only lethal high voltage

and temperatures above 500°C will demagnetize this material.

CHAPTER III

MATERIALS AND METHODS

A. Surgical Procedure

Young adult, apparently normal, mongrel dogs were selected at random from the animal quarters without regard to sex or breed. All instruments which were to be used on the animals were sterilized by autoclaving them prior to their use. The surgical procedures were carried out in three stages.

STAGE I - Anesthesia of the animals was induced by intraperitoneal injection of 1 c.c. of a 5% solution of sodium pentobarbital (nembutal, Abbot) per 3.5 lbs. body weight. The animals were in a stage of surgical anesthesia in approximately fifteen minutes.

After securing the animals to the operative table, each dog was draped with sterile towels and a mouth prop and throat pack were put into place.

With a number fifteen blade mounted on a Bard Parker scalpel, an incision was made through the attached gingiva from the lower left first molar to the distal of the lower left canine on both the buccal and lingual sides of the teeth. A mucoperiosteal flap was prepared, the

mucous membrane and periosteum being carefully reflected away from the body of the mandible. The lower left third and fourth premolars were fractured and removed with the aid of a straight elevator and a lower bicuspid extraction forceps (Number 151).

Any remaining sharp bony areas were rounded off with a bone file and after careful debridement, the mucoperiosteal flap was repositioned and sutured with 000 black silk using interrupted sutures.

STAGE II - This procedure was carried out approximately six weeks after the premolar teeth were extracted. Anesthesia of the animal was induced in the same manner as it was for the first surgical procedure and the animals were similarly prepared.

Once again, using a number fifteen blade mounted on a Bard Parker scalpel, an incision was made through the attached gingiva along the buccal of the lower left first molar tooth continued through the mucous membrane and periosteum along the crest of the edentulous premolar area, and terminated at the distal end of the canine tooth. A mucoperiosteal flap was reflected buccally and lingually exposing the mandible in the edentulous area. Under a stream of sterile normal saline solution, a bony vault was prepared on the crest of the mandible with the aid of a 559 carbide fissure bur mounted in a dental handpiece. A

sterile magnetic implant magnetized through its diameter composed of platinum-cobalt alloy in the shape of a flattened cylinder which is capable of sustaining a load of 100 grams and possesses a magnetic force of 3,283 oersteds, measuring approximately one-fourth inches in length, less than one-eighth inches in height, and a little more than one-eighth inches in width was used as a template to facilitate the construction of the vault. (Precise dimensions of the implant are: 0.25" x 0.14" x 0.10" or 6.35 x 3.55 x 2.54 mm.). The vault was finished with a bone file, debrided with an excavator, and flushed with normal saline solution.

Prior to insertion of the implant, the tantalum mesh attached to it was removed. According to Behrman (1960) there is no need for this tantalum mesh to provide "reinforcement" of the overlying mucoperiosteum. He said the mesh is attached to the magnet primarily to prevent it from rotating in the vault in the bone and, secondarily to suspend it in position at a level with the bony margins if the vault is prepared too deeply. Since neither of these problems were encountered it was felt that removal of the mesh would facilitate implantation in the dogs.

The implant was then placed in the vault and carefully positioned so that it was flush with the bony margins surrounding it. The mucosa

and periosteum were reapproximated to their normal position to cover the implant and sutured to place using several interrupted 000 black silk sutures. While suturing, the implant was held in place with pressure from an orangewood stick to be sure that it would be retained in the vault and not rotate with the metal instruments. Before returning the animals to their cage, an impression of the implant site and adjacent teeth was taken using impression compound.

This impression was poured up in dental stone (Coecal) and was used for construction of an acrylic splint which was to contain the attracting denture magnet. Prior to the construction of the splint, the model was painted with tinfoil substitute and a block of wax positioned on it so that there was a space created for the denture magnet. This space was continuous with a "window" which was on the buccal side of the splint. Using self-curing acrylic (Duz-All), a splint was constructed with the following modifications. A slot was placed on the lingual side so that a dental x-ray film could be placed into it and remain in a constant position. On the buccal side of the splint, an edgewise buccal tube was inserted into the acrylic so that it was perpendicular to the film slot on the lingual. The purpose of this tube was to hold a

removable rectangular wire which would be inserted at the time radiographs were taken and thus get a constant positioning of the x-ray tube by always paralleling it to the wire. The wax was then removed from the splint and it was trimmed on a lathe so that there was no over-extention of the borders and it was out of occlusion. Final polish was given the splint using pumice and white diamond.

STAGE III - Approximately two to six weeks after stage two, the animals were once again anesthetized and prepared in the manner previously described. An attracting denture magnet, identical to the implant magnet, was placed on the crest of the edentulous ridge over the implant site and allowed to align itself up with the attracting implant. The denture magnet was then covered with the previously prepared acrylic splint. By viewing through the "window" on the buccal side of the splint, it was made certain that the splint was not impinging on the magnet so that a pressure area would be created.

While holding the splint in place, the magnet now in alignment with the attracting implant, was incorporated into it by adding self-cure acrylic through the buccal "window" so that the entire space was filled in. After the acrylic had set, the splint was removed and polished. The splint was then placed back into the mouth and a careful

check was made to see that it was out of occlusion and the borders were not over-extended. The splint was then immobilized to the jaw using two twenty-five gauge stainless steel circumferential wires which were passed with the aid of a seventeen gauge hollow needle.

B. Post-Operative Care

All of the animals were given intramuscular injections of 600,000 units of long-acting penicillin (Bicillin, Wyeth) immediately after surgery. The diet consisted of a mixture of Purina dog meal and freshly ground horse meat. This mixture was kept soft for the first forty-eight hours after surgery. The diet was supplemented with Lolli-Pups (Charcoal, Ca, PO_4, Vitamins A, D, B_1, B_2, Niacin, and Chlorophyll) and fresh water was always available. Instructions were given to the caretakers to report any changes in the behavior of the animals and observations and progress notes were made periodically.

Whenever possible, the animals were transported to the dental school and radiographs were taken at this time. The radiograph exposure time was one second at 10 M.A. and 65 K.V.P. Radiographs were also taken of all the specimens at the time of sacrifice.

C. Preparation of Specimens

By means of a lethal dose of sodium pentobarbital the animals were sacrificed at intervals of twenty-four hours, seventy-two hours, one week, two weeks, one month, two months and three months. The specimens were removed surgically by means of a gigli saw and placed in 10% formalin solution. The solution was changed in twenty-four hours and the specimens remained in it until fixation was completed. The specimens were then decalcified in formic acid sodium citrate solution, embedded in celloidin and cut at eight to ten microns. The sections were stained by hemotoxylin and eosin and used for histopathologic study.

D. Changes in Procedure

Several modifications in the surgical procedure were made after examining some of the early specimens. A healing period of two weeks was allowed between stage two and three. This was later increased to four weeks and then eight weeks. The flap design was also modified. Instead of reflecting the mucosa from the crest downward in stage two, the incision was made near the buccal sulcus and the mucosa was reflected upward toward the crest of the mandible, thus establishing a reverse flap. It was thought that this would facilitate healing since

closure would not be made over a foreign body, in this case the implant.

In the early specimens the denture magnet was placed directly on the mucosa when it was incorporated into the splint. In the later procedures, a single layer of thirty gauge relief wax was placed between the denture magnet and the mucosa covering the implant.

In addition to the procedure already mentioned, two more animals were used in which a pair of attracting magnets were implanted into the body of the mandible, with approximately 1.5 mm. of bone between them. These animals were sacrificed at seventy-two hours and two months.

CHAPTER IV

FINDINGS

A. Macroscopic Findings

Experimental Animals

In all specimens, the acrylic splint and circumferential wires holding it were still in place. The one and two month specimens had a slight amount of movement of the splint, and in the three month specimen the splint was very mobile. All specimens showed varying amounts of redness of the mucosa around the circumferential wires. In the one and three month specimens, there was an ulceration of the mucosa around these wires, while in the two month specimen this same area exhibited a moderate amount of redness with little swelling. A moderate swelling of the jaw was noted in the area of the wires on the twenty-four and seventy-two hour specimens.

In the one week and three month specimens, there was a moderate reddening of the mucosa near the border of the splint. In almost all of the specimens, the mucosa beneath the splint appeared to be normal. This mucosa in the three month specimen displayed a slight amount of reddening, and seemed to have an irregular surface.

Upon removal of the splint, the implant magnet was drawn out of the soft tissues except for the twenty-four and seventy-two hour specimens. The implant magnet was either partially or totally in contact with the denture magnet in all cases but the twenty-four hour specimen. In the twenty-four hour specimen, the mucosa over one corner of the implant failed to heal and this portion of the implant was exposed but not in contact with the denture magnet. The tissue in this area was reddened and the margins of the opening were somewhat rolled and elevated. In the seventy-two hour specimen, the posterior half of the implant was still covered by soft tissue, while the anterior portion was in contact with the denture magnet. The tissue covering this implant was very thin, almost transparent, and appeared gray in color. In the remaining specimens, a depression, conforming to the shape of the implant, was left in the soft tissues. On the inner surface of this depression, the mucosa was smooth and glistening and seemed to be of a normal pinkish-gray color.

Intraoral periapical radiographs were taken at the time of sacrifice on all specimens and whenever possible, they were also taken at the time the splint was put into place. Those taken at the time of placement

of the splint show a distance of approximately 1.0 mm. between the two magnets.

The radiographs of the twenty-four and seventy-two hour specimens were the only ones which demonstrated any separation between the magnets at the time of sacrifice. The twenty-four hour specimen had a distance of approximately 0.9 mm. between the magnets. The magnets of the seventy-two hour specimen were approximately 0.7 mm. apart at their posterior end and were in contact at their anterior end at the time of sacrifice. Radiographs of the other specimens showed the magnets in contact with each other when the animals were sacrificed. There was a slight radiolucency in the bone immediately adjacent to the implant in all of these specimens.

The only other finding seen in the radiographs was noted at the inferior border of the mandible around the circumferential wires. There was a radiolucency of the bone in these areas and this was visible only in the one, two, and three month specimens. This was only slight in the one month specimen while in the two month specimen, the radiolucency extended half way through the cortical plate of bone. In the three month specimen, the radiolucency was quite large and extended up to the inferior alveolar canal.

Control Animals

Two animals were used which had a pair of attracting magnets implanted into the body of the mandible. One was sacrificed at seventy-two hours and the other at the end of two months.

In the seventy-two hour specimen there was a slight swelling of the jaw. The line of incision was clearly visible and the sutures were still in place. There was a slight reddening of the mucosa in this area. The two month specimen healed very well and there was no evidence of the incision present. The mucosa appeared normal in color and texture and was firmly attached to the body of the mandible.

Radiographs taken at the time of sacrifice show a distance of approximately 1.5 mm. between the magnets in the seventy-two hour specimen. In the two month specimen, the magnets are approximately 1.5 mm. apart at their superior ends and appear to be in contact at their inferior ends. There is a slight radiolucency between and around the inferior one-half of these magnets.

B. Microscopic Findings

<u>Dog No. 1 Twenty-four Hour Specimen</u>

Healing after extraction - Four weeks

Healing after implantation - Two weeks

Mucoperiosteal flap - Reverse type

Relief wax under denture magnet - Present

The cells of the epithelial layer of mucosa overlying the implant appear compressed and are seen as layers of long, flat cells. The nuclei of these epithelial cells in the superficial layers shows evidence of caryorrhexis while those near the basement membrane appear to be pyknotic. There is also some hydropic degeneration present.

Swollen collagenous fibers along with many compressed cells are seen in the lamina propria. These cells are fibroblasts along with a few lymphocytes and polymorphonuclear leukocytes. The cytoplasmic outline of most of these cells is very indistinct. Capillaries are few in number and those present are very small and appear compressed.

A fibrous connective tissue capsule lines the defect which contained the implant magnet. This capsule is thin and dense at the sides of the vault and at the base of the vault it is thick and loosely arranged. This tissue contains many young proliferating fibroblasts and a few polymorphonuclear leukocytes and undifferentiated reserve cells. A moderate amount of capillaries are seen in the connective tissue at the base of the implant along with a few bone spicules.

Many of the trabeculations in the cancellous bone surrounding the implant show lacunae which are devoid of osteocytes. Near the base of the implant are a few reversal lines and a layer of osteoid tissue. A few osteoclasts are seen on the edges of the bone at the sides of the implant. Most of the marrow spaces contain little or no loose connective tissue.

Dog No. 2 - Seventy-two Hour Specimen

Healing after extraction - Eight weeks

Healing after implantation - Three weeks

Mucoperiosteal flap - Reverse type

Relief wax under denture magnet - Present

A portion of the mucosa which was covering the implant is ulcerated. That portion which remains shows the epithelial layer to be very thin and there is an absence of the rete pegs which are normally seen. Many of the epithelial cells show evidence of caryor-rhexis and chromatolysis along with some hydropic degeneration.

The lamina propria contains very few capillaries which are extremely dilated. The collagenous fibers appear to be swollen and there is a slight infiltration of lymphocytes and polymorphonuclear leukocytes. A capsule consisting of loose connective tissue lines the

space which contained the implant magnet. In some areas this capsule is continuous with the marrow spaces of the cancellous bone.

The surface of bone at the base of the implant contains many osteoclasts and a few osteoblasts. Reversal lines are evident near the bony surfaces which surround the implant magnet. Several areas of bone have lacunae which are devoid of osteocytes. In general the marrow spaces appear normal except for an increase in the loose connective tissue.

Dog No. 3 - One Week Specimen

Healing after extraction - Nine weeks

Healing after implantation - Six weeks

Mucoperiosteal flap - Normal, incision on crest of ridge

Relief wax under denture magnet - None

The epithelium is ulcerated and the bony vault which was prepared for the magnetic implant is filled in with fibrous connective tissue. This tissue shows moderate vascularity. There is evidence of proliferation of many young fibroblasts which have spindle-shaped nuclei and long cytoplasmic processes typical of cells seen in immature connective tissue.

In addition to the fixed cells, fibroblasts and vascular endothelium,

there is a frequent number of wandering indifferent loose connective tissue cells. These cells are mainly located near the two surfaces of the lamina propria; next to the implant and next to the bone. Lymphocytes are evident throughout the lamina propria in vast numbers and there is a scattering of polymorphonuclear leukocytes limited to the superficial portion of this tissue.

Numerous reversal lines are seen at the base of the prepared bony vault; and evidence of osteoclastic activity is present on the surface of bone at the base of the connective tissue capsule which separated the implant from bone. There are several areas at the margins of the bony vault where the lacunae are devoid of osteocytes. The marrow spaces adjacent to the base of the bony vault show an increase in loose connective tissue and in some areas osteoblastic activity while in other areas, osteoclastic activity.

Dog No. 4 - Two Week Specimen

Healing after extraction - Seventeen weeks

Healing after implantation - Eight weeks

Mucoperiosteal flap - Reverse type

Relief wax under denture - Present

There is a defect in the soft tissues conforming to the shape of

the implant magnet. On the inner surface of this defect is a layer of stratified squamous epithelial cells of approximately two to four cells thickness. A large number of dilated capillaries and inflammatory cells are found in the upper half of the lamina propria, while the lower half is mainly composed of fibroblasts and collagenous fibers making up a dense fibrous capsule which appears more mature than the one seen in the one week specimen.

Lymphocytes are most abundant along with many macrophages, plasma cells, polymorphonuclear leukocytes, and a few undifferentiated or reserve cells. The macrophages and polymorphonuclear leukocytes are evident in the superficial lamina propria next to the metal implant.

Osteoblasts are now visible at the base of the bony vault and reversal lines are evident indicating new bone apposition. The trabeculae of the cancellous bone show some osteoclasia and the marrow spaces show some evidence of apposition of bone with little vascularity or inflammation.

Dog No. 5 - One Month Specimen

Healing after extraction - Ten weeks

Healing after implantation - Two weeks

Mucoperiosteal flap - Normal, incision on crest of ridge.

Relief wax under denture magnet - None

The epithelium is ulcerated and there is a visible defect in the lamina propria created by the implant magnet. A few bacterial plaques which were beneath the magnet are still present on the surface of the base of the defect. The area immediately adjacent to the implant shows moderate infiltration of polymorphonuclear leukocytes and plasma cells. The plasma cells are extruding their cytoplasmic contents. Proliferating capillaries are present but not in as great an amount as seen in the two week specimen. Beneath the zone of inflammatory cells is a dense mature fibrous connective tissue capsule.

New bone has filled in the defect created by the lost magnet. Osteoblasts are evident and reversal lines demarcating the old and new bone are quite sharply defined. There is some osteoclastic activity seen on the surface of bone which served as a base for the implant. In general, the cancellous bone shows a picture of normal bone with no inflammation present. Most of the marrow spaces show a slight increase in loose connective tissue with moderate vascularity.

Dog. No. 6 - Two Month Specimen

Healing after extraction - Seven weeks

Healing after implantation - Five weeks

Mucoperiosteal flap - Normal, incision on crest of ridge

Relief wax under the denture magnet - None

The epithelium next to the implant shows hydropic degeneration and over the implant it is ulcerated. The lamina propria contains dilated capillaries along with a considerable amount of inflammatory cells. Lymphocytes are present along with a few polymorphonuclear leukocytes and plasma cells. The plasma cells are extruding their cytoplasm and this appears to be separating the fibers in the connective tissue capsule that was beneath the implant. This capsule is of a dense, mature nature.

The bony vault which was prepared for the implant magnet is no longer present. Near the base of this vault are reversal lines upon which new bone has been laid down. Some osteoblasts are still active laying down new osteoid tissue. The marrow spaces contain some plasma cells which are liberating their cytoplasm but, in general, they appear normal and show more vascularity than seen in the one month specimen.

Dog. No. 7 - Three Month Specimen

Healing after extraction - Nine weeks

Healing after implantation - Six weeks

Mucoperiosteal flap - Normal, incision on crest of ridge

Relief wax under denture magnet - None

The epithelium which was over the implant magnet is ulcerated. The lamina propria beneath this implant contains a large amount of dilated capillaries, plasma cells, and polymorphonuclear leukocytes scattered throughout its entire depth. The collagenous fibers and fibroblasts are mainly at the base of the lamina propria, next to the bone. This capsule shows a picture of dense fibrosis, but its fibers are separated by the inflammatory cells.

The surgical defect created in the bone is now filled in with new bone covered by a periosteum. Numerous reversal lines are present and the lamellae of the bone show many irregular and concentric patterns in this area. Osteoblastic and osteoclastic activity is minimal and the marrow spaces appear normal.

Dog No. 8 - Seventy-two Hour Control

1) Cross Section of Mandible

The defect created by preparing a vault for the implant is surrounded by bone on its superior, inferior, and lingual surfaces and by soft tissue on its buccal surface. This soft tissue is a dense fibrous connective tissue and contains many muscle fibers near its

surface. On the inner-most surface of this tissue is a remnant of an attached fibrin clot containing many polymorphonuclear leukocytes. This tissue also contains a moderate number of reserve or undifferentiated cells.

On the cut surface of the cancellous bone, remnants of a blood clot are seen to be continuous with the loose connective tissue of the bone marrow. There is a large number of polymorphonuclear leukocytes present in this area and they extend down into the marrow spaces. The tissue in this area also contains many young fibroblasts and some undifferentiated or reserve cells along with some spicules of bone. A few osteoclasts are seen on the cut surfaces of the cancellous bone trabeculae and in some areas the lacunae appear to be devoid of their osteocytes.

2) Longitudinal Section of the Mandible

The soft tissue covering the cortical plate of bone that was between the implants is a fibrous connective tissue and contains many muscle fibers and a large number of polymorphonuclear leukocytes. The cortical plate of bone and the trabeculae of the cancellous bone that was between the implants contain many lacunae that are devoid of osteocytes. There is no osteoclastic or osteoblastic activity visible.

The marrow spaces of the cancellous bone show proliferation of many fibroblasts and some fat is present which is undergoing degeneration. Bone spicules are scattered throughout the marrow spaces and around the trabeculae of the cancellous bone. There is very little vascularity seen in the marrow spaces between the implant sites.

Dog No. 9 - Two Month Control

Longitudinal Section of the Mandible

The two defects created for the implants in the body of the mandible are surrounded by a dense fibrous connective tissue capsule. This capsule is composed of many densely packed collagenous fibers and a moderate amount of fibroblasts on the superior, inferior, and lateral surfaces of the implant vault. The capsule on the medial surface of the vault, that side where one implant was facing the other, appears to be composed of many swollen collagenous fibers and a large number of compressed fibroblasts whose nuclei show evidence of chromatolysis. The surface of the capsule next to the intervening bone that was between the implants contains a large amount of macrophages.

At the superior end of the implants, the remaining cortical and cancellous bone that was between the magnets contains many lacunae that are devoid of their osteocytes. The surface of this bone is lined

with many osteoclasts which seem to increase in number as the inferior surface of the implant vaults is approached. At the inferior surface of the implants, the area where the magnets appeared to be in contact on the radiographs, there is only a slight amount of bone present between the two implants. In some areas this bone is completely absent. The intervening bone that remains is completely devoid of osteocytes and is surrounded by many osteoclasts. Where there is an absence of bone, the two fibrous tissue capsules that were surrounding the implants appear to have come together and are now seen as a single layer of fibrous connective tissue separating the implants. This tissue contains a few capillaries that appear to be compressed.

CHAPTER V

DISCUSSION

Abati (1961) studied the response of the oral mucosa and bone in dogs to a single, non-attracting magnetic implant composed of a platinum-cobalt alloy. He found that at the end of a six month period, the gross appearance indicated no significant change in the oral mucosa. Histologic examination of the defect created for the implant revealed the progress that occurred from the formation of a blood clot to the complete healing of the defect with the formation of a connective tissue capsule around the implant.

In the present investigation, the feasiability of the implantation of a pair of attracting platinum-cobalt magnets in oral prosthesis was studied. After implanting one magnet into the mandible of a dog and allowing the mucosa to heal over it, an acrylic spint containing an attracting magnet was placed over the implant and immobilized with circumferential wires around the mandible. It was found that the continuous use of a pair of attracting platinum-cobalt magnets results in the implant magnet being attracted to, and drawn out of its bony vault by the denture magnet. All of the specimens which were studied showed this finding.

After observing the early specimens, it was thought that the loss of the implant was due to the type of mucoperiosteal flap that was constructed. An incision was made through the mucosa along the crest of the alveolar ridge resulting in an area of fresh scar tissue between the magnets. This tissue would be easily subject to an ulceration if the magnets had exerted any pressure on it. A modification was made and a reverse flap was constructed to eliminate the fresh scar tissue in an incision between the magnets but the findings remained the same, the implant magnet being drawn out of its vault.

At the time that the denture magnet was being aligned with the implant magnet, it was thought that the denture magnet was exerting a pressure on the intervening mucosa due to the attraction attributed to the magnetic forces. If this were true, when the denture magnet was incorporated into the acrylic splint, this same pressure would be transmitted to the mucosa when the splint was put into place. This pressure would then be capable of causing a necrosis or atrophy of the mucosa covering the implant and the result would be an ulceration of the mucosa with a loss of the implant magnet. To eliminate this alleged external pressure, a single layer of thirty gauge relief wax was placed between the denture magnet and the alveolar mucosa covering

the implant. However, the implant magnet was still drawn out of its vault and up through the alveolar mucosa so that it was eventually positioned against the denture magnet.

Allowing two weeks for healing after implantation of the magnet and before insertion of the splint with the attracting denture magnet was thought to be too brief a period of time, since Abati (1961) showed a dense fibrous tissue capsule surrounding the implant does not appear until four weeks after implantation. This period of healing was varied to intervals ranging from the minimum of two to a maximum of eight weeks. In all cases, the implant magnet still was being drawn out of its vault by the attracting denture magnet.

The animals behaved normally and were able to eat without any difficulty. Gross examination of the tissues after removal of the splint at the time of sacrifice revealed no signs of inflammation such as pus, redness, or swelling of the tissues. The possibility of infection being eliminated, it was then thought that the implant was lost due to either a foreign body reaction or else the physical attraction of one magnet for the other overcame the ability of the tissues to retain the implant magnet.

Histologic examination of the specimens revealed an absence of foreign body giant cells in all cases. The inflammatory cells which

were present in the lamina propria were seen in moderate amounts and were mainly located in the superifical portion of this tissue. Abati (1961) reported seeing a slight inflammatory process in the mucosa immediately after implantation of a platinum-cobalt magnet in the mandible, but said that at the end of one month there was a complete absence of inflammatory cells in this area. His findings would then lead one to assume that, in this investigation, at the time the spint was placed into the mouth, there was a complete absence of inflammatory cells in the mucosa since healing progressed normally. The appearance of the inflammatory cells would then have to be attributed to an irritation produced by the splint and by the implant magnet as it moved out of its bony vault towards the oral cavity.

Pressure of the splint caused a compression of the alveolar mucosa which was between the intaglio of the splint and the implant magnet. Usually, as is the case in denture wearers, this pressure would cause a resorption of the bone beneath the splint and the alveolar mucosa would not undergo any degenerative changes. However, in this case, the mucosa contained the metal implant on its undersurface. The metal was not capable of undergoing any resorption to cushion the pressue from the splint and an inflammatory process was initiated in the mucosa.

This process of inflammation was further contributed to by the movement of the splint when the bone supporting the circumferential wires began to resorb, as was reported in the radiographic findings.

The polymorphonuclear leukocytes seen near the surface of the lamina propria served to control infection and prevent ingress of micro-organisms into the implant site. The lymphocytes provided additional control of infection, probably by antibody production, and thus served as a secondary defense throughout the entire depth of the tissue. This cellular layer formed the barrier to bacterial infection commonly seen in a granulating surface. Clasmatolysis observed in some of the plasma cells was an indication that these cells were performing their primary function. By extruding their cytoplasm, antibodies were released. Also upon degeneration, these cells were releasing their proteins, polypeptides, and nucleic acid fractions for use by proliferating cells taking part in the reparative process.

The reparative process was evidenced by an increase in fibrous connective tissue resulting in a thickening of the capsule at the base of the implant. Initially, as reported by Abati (1961), the mucosa over the implant healed completely and the implant was surrounded by a dense fibrous connective tissue capsule. As the implant approached

the oral cavity, the area beneath it was filled in with granulation tissue containing many fibroblasts, collagenous fibers, and a large number of dilated capillaries. This tissue was eventually converted into an organized fibrous tissue, a process known as cicatrization. Undifferentiated reserve cells seen near the surface of the connective tissue were able to contribute to the increase in thickness of the capsule by differentiating into fibroblasts.

The early specimens, twenty-four and seventy-two hours, which still had a portion of the alveolar mucosa between the magnets showed evidence of a pressure necrosis in this tissue. The remaining epithelial cells contained nuclei which were broken up into a number of small fragments. This process of caryorrhexis was accompanied by chromatolysis where the nuclear chromatin appeared to be dissolved giving the appearance of a cell which was devoid of its nucleus. These nuclear changes are quite indicative of the cellular changes observed in necrosis. The necrosis was not only due to a pressure from the splint, but since the position of the denture magnet was fixed, the implant magnet also created a pressure by being attracted by, and up to the denture magnet. As the implant approached the oral cavity, the mucosa underwent atrophy and ulcerated, allowing the implant to be lost through

the break in the tissues.

All of the specimens show some evidence of bony repair following implantation of the magnet. Reversal lines in the bone surrounding the implant are evident, demarcating areas where new bone was laid down. In the early specimens, twenty-four and seventy-two hours, osteoblastic activity was slight and the new bone was identified as osteoid tissue. The greatest amount of osteoblastic activity was observed in the one week to one month specimens. In the two month specimen, the osteoblasts became fewer in number and by three months they were almost completely absent and a dense cortical plate of bone covered by a periosteum was evident once again.

Osteoclasts were present on the surface of bone surrounding the implant in almost all of the specimens. Abati (1961) reported little osteoclastic activity one month after implantation. The presence of osteoclasts in this investigation can only be explained by the fact that the loosening of the splint, as previously mentioned, not only irritated the mucosa, but also compressed the bone beneath the implant. In conjunction with the loose splint was the presence of bony spicules in some areas adjacent to the bony surface. This entrapped necrotic bone together with the loose splint could well have served as the stimulus for

the osteoclasts to form on the surface of bone adjacent to the implant. The undifferentiated reserve cells seen at the base of the connective tissue probably served as a source of these cells by differentiating into osteoclasts.

Histologic examination of the two month control animal shows that the bone between the implants contains many lacunae devoid of osteocytes. This necrosis of bone can be interpreted as a result of either injury to the bone by the bur used in preparing the two vaults or else the physical attraction of one magnet for the other caused a compression of this intervening bone resulting in pressure necrosis. Since Abati (1961) reported that at one month remodeling of the bone was almost complete, this would indicate that the necrosis was due to a compression brought about by the magnetic forces. This is further evidenced when one realizes that in the control specimens, there was a complete absence of any external factors, such as the splint or the wires, to act upon the intervening bone.

The radiographs taken at the time of sacrifice of the animals show that when one magnet is in the mandible and the other in an acrylic splint, the two magnets are partially in contact with each other at seventy-two hours and in total contact at one week. In the control

animals where the magnets were separated by approximately 1.5 mm. of bone at the time of their implantation, the radiograph shows that at seventy-two hours the magnets were still 1.5 mm. apart. At two months, the magnets were in contact at their inferior ends. This suggests that the presence of the splint containing a magnet and its continuous use did cause a hastening of the loss of the implant, since it was lost much earlier when the splint was used. However, this also points out the fact, that if the attracting magnets are in continuous apposition, it is only a matter of time before the physical attraction created by the magnetic forces results in the implant magnet being drawn toward the denture magnet, and an eventual loss of the implant.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This investigation was designed to study the feasibility of the implantation of a pair of attracting platinum-coblat magnets in oral prosthesis. A sterile magnetic implant composed of a platinum-cobalt alloy (platinum 77% and cobalt 23%) was implanted into the mandible of seven young adult mongrel dogs. An acrylic splint containing a similar attracting magnet was placed on the alveolar ridge over the implant and secured by means of circumferential wires around the mandible. Two additional animals in which a pair of these magnets was implanted into the body of the mandible, were used as controls. The animals were sacrificed at intervals ranging from twenty-four hours to three months and histologic studies were made of the prepared specimens.

Several variations in procedure were made and these consisted of:

1. Construction of a normal mucoperiosteal flap by incising the mucosa on the crest of the alveolar ridge, and a reverse type flap by making an incision in the buccal sulcus.

2. Use of a single layer of thirty gauge relief wax between the

denture magnet and the alveolar mucosa in some animals, while in others the wax was omitted.

3. Varying the time of healing after implantation and before insertion of the splint containing the denture magnet from two to eight weeks.

In all of the specimens observed, the implant magnet was attracted to, and drawn out of its bony vault by the denture magnet.

Gross examination of the specimens indicated no significant change in the oral tissues at the time of sacrifice. No oral lesions were encountered, and the animals seemed to be totally unaffected by the splint and the magnets.

Histologic examination of the tissues revealed an absence of any foreign body reaction. An irritation caused by the acrylic splint and the movement of the implant magnet toward the oral cavity, resulted in an inflammation of the lamina propria surrounding the implant. There was a pressure necrosis of the mucosa between the magnets beginning twenty-four hours after the splint and attracting denture magnet were in place, and this together with the inflammation resulted in an ulceration of the tissues in seventy-two hours, with a loss of the implant after seventy-two hours. Following loss of the implant, new bone was laid

down to fill in the vault prepared for the implant and the soft tissue defect healed by second intention.

Radiographs taken at the time of sacrifice of the animals shows that when the splint was in continuous use, the two magnets were in partial contact with each other in seventy-two hours and in total contact at one week. The magnets in the two control animals were separated by approximately 1.5 mm. of bone at the time of their implantation. Radiographs taken when these animals were sacrificed show that at seventy-two hours the magnets are separated by 1.5 mm. of bone but are in contact at their inferior ends at the end of two months.

From this investigation it was found that:

1. Implantation of a platinum-cobalt magnet in the mandible of a dog initially results in normal healing and the magnet becomes surrounded by a fibrous connective tissue capsule.

2. Continuous use of an acrylic splint, from twenty-four hours to three months, containing an attracting magnet results in a mild inflammation of the mucosa with the implant magnet being attracted to, and drawn out of its bony vault by the denture magnet within seventy-two hours.

3. Following loss of the implant, healing occurs and the prepared

bony vault is eventually filled in by new bone.

A study utilizing a removable appliance so that intermittent use of attracting magnets can be evaluated should follow this investigation.

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FIGURE 1

Color photograph showing prepared bony vault on the crest of the alveolar ridge prior to insertion of the implant.

APPENDIX

A. Photographs of Methods

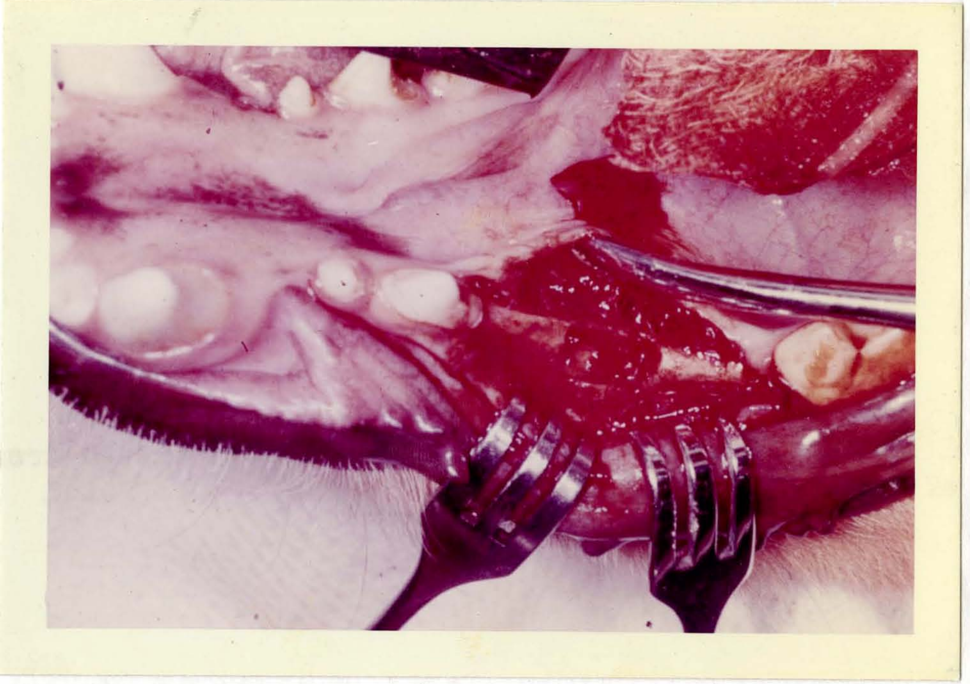

FIGURE 1

FIGURE 2

Color photograph showing implant magnet in position in its bony vault. The tantalum wire mesh has been removed from the magnet.

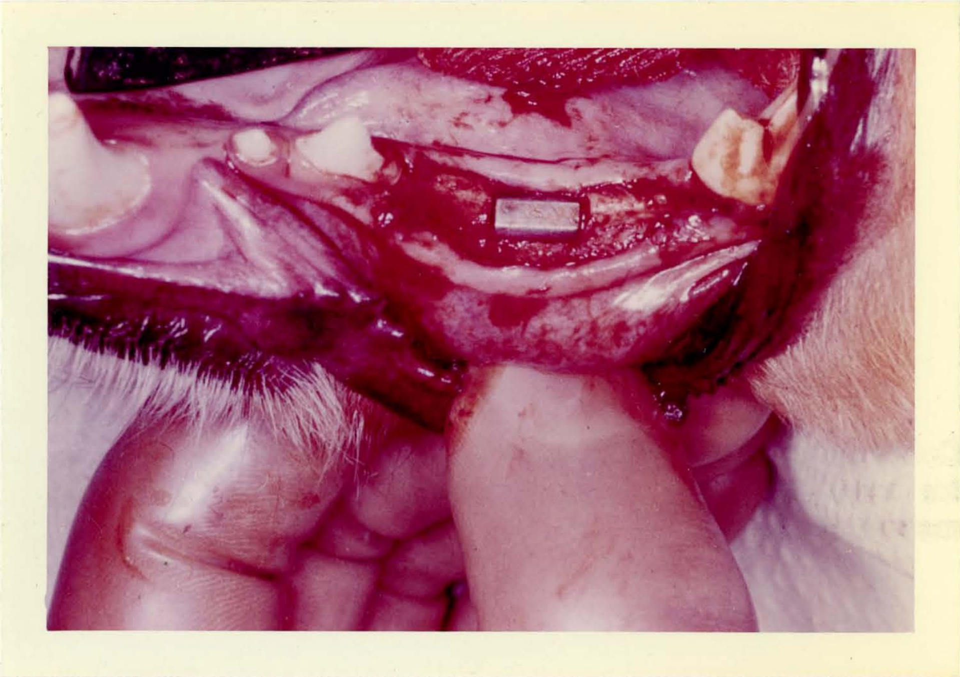

FIGURE 2

FIGURE 3

Color photograph showing the closure of the mucosa over the implant. Interrupted sutures were placed, using 000 black silk.

FIGURE 3

FIGURE 4

Color photograph taken six weeks post-operatively. The implant magnet is completely covered by the mucosa.

FIGURE 4

FIGURE 5

Color photograph showing the acrylic splint, now containing the denture magnet, being held in place with two 25 ga. stainless steel circumferential wires.

FIGURE 5

FIGURE 6

Color photomicrograph X 25 of one week specimen showing fibrous connective tissue filling in the prepared bony vault. H & E.

FIGURE 7

Color photomicrograph X 100 of one week specimen showing capillary and inflammatory cell infiltration of the fibrous connective tissue capsule which was adjacent to the implant magnet. H & E.

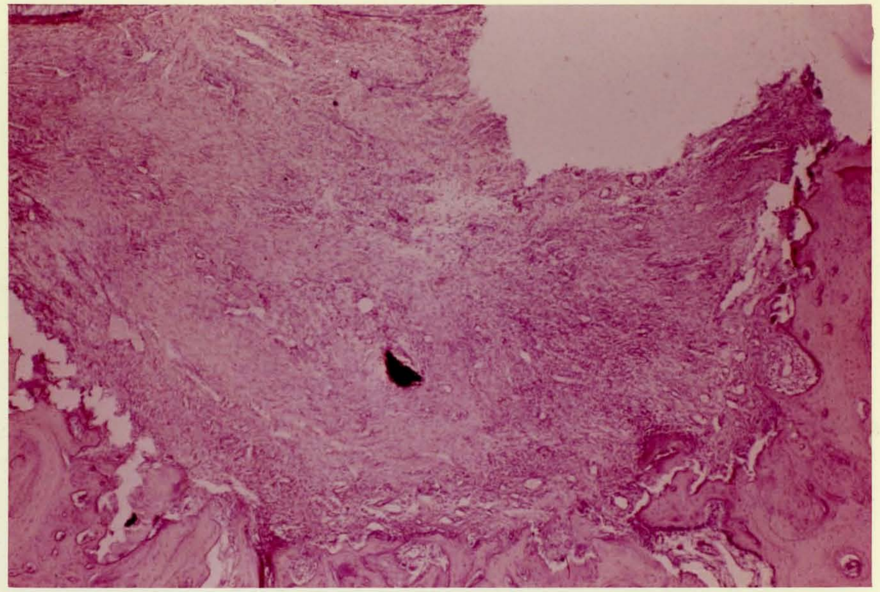

FIGURE 6

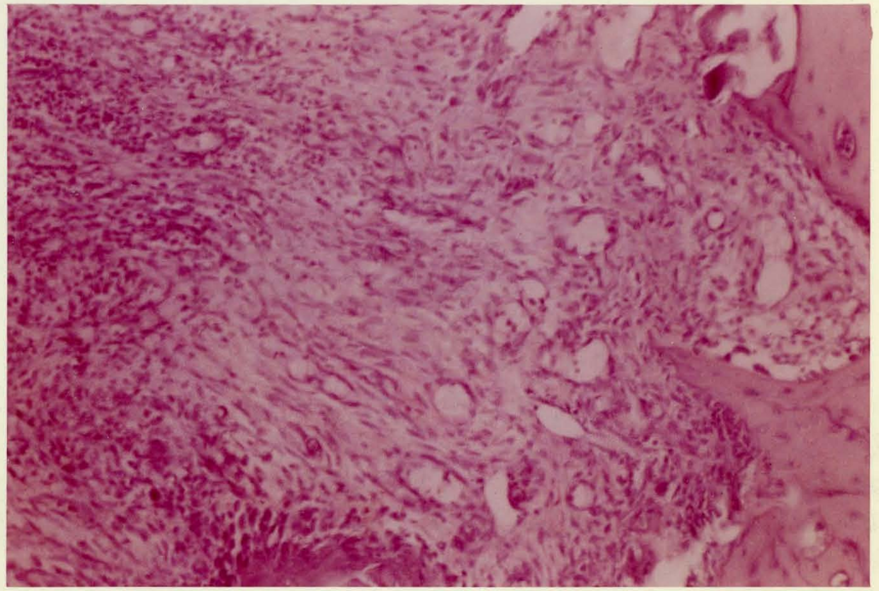

FIGURE 7

FIGURE 8

Color photomicrograph X 800 of one week specimen showing polymorphonuclear leukocytes which are contained near the surface of the lamina propria. H & E.

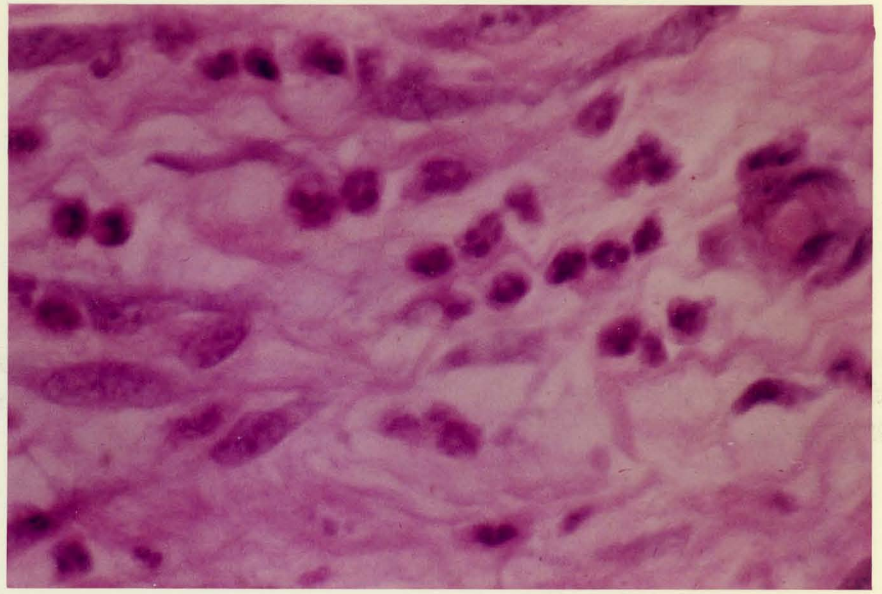

FIGURE 8

FIGURE 9

Color photomicrograph X 160 of two week specimen showing a large number of dilated capillaries and inflammatory cells found in the upper portion of the lamina propria. The space which contained the implant magnet is in the upper left corner. H. & E.

FIGURE 10

Color photomicrograph X 250 of two week specimen showing the lower portion of the lamina propria which was mainly composed of fibroblasts and collagenous fibers making up a dense fibrous capsule. H. & E.

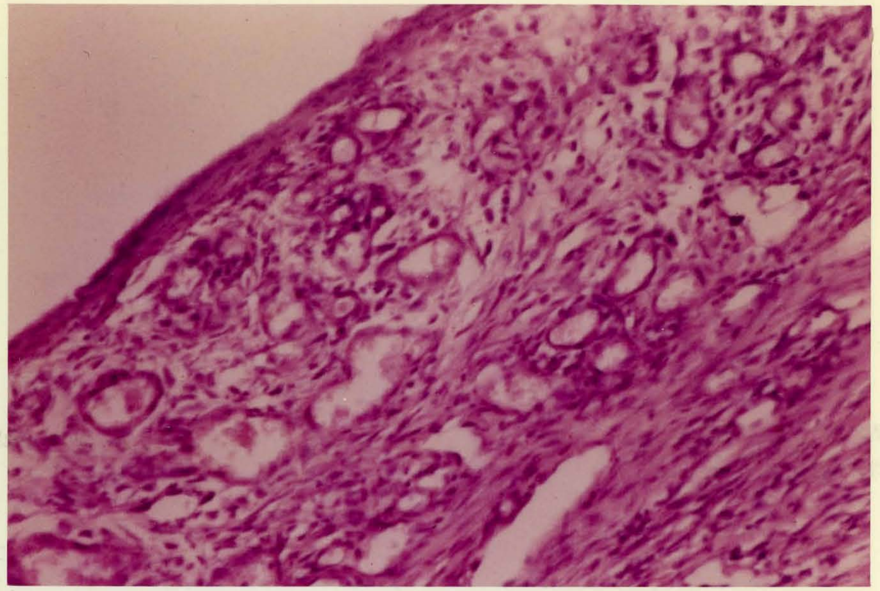

FIGURE 9

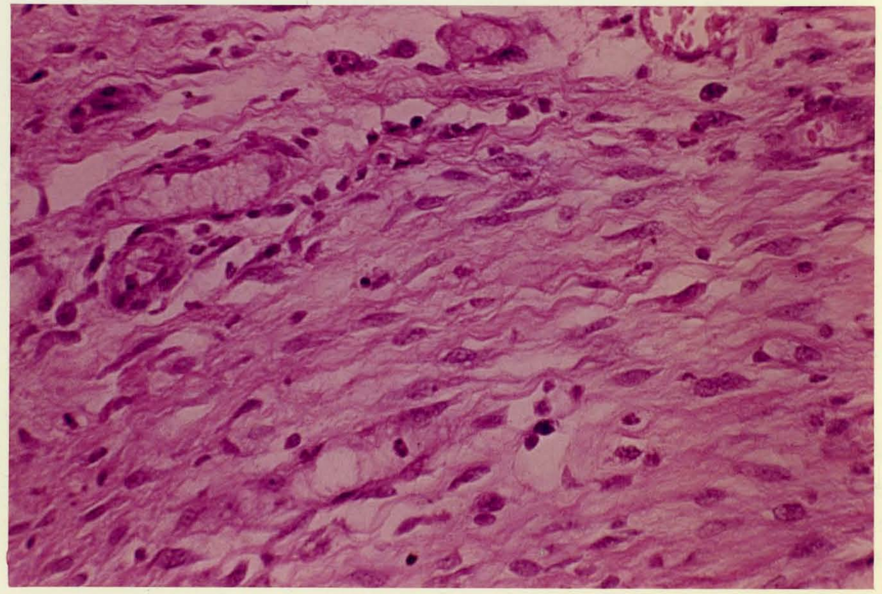

FIGURE 10

FIGURE 11

Color photomicrograph X 80 one month specimen showing a zone of inflammatory cells adjacent to the implant and a dense mature fibrous connective tissue capsule between the implant and the bone. The space which contained the implant is on the right side. H & E.

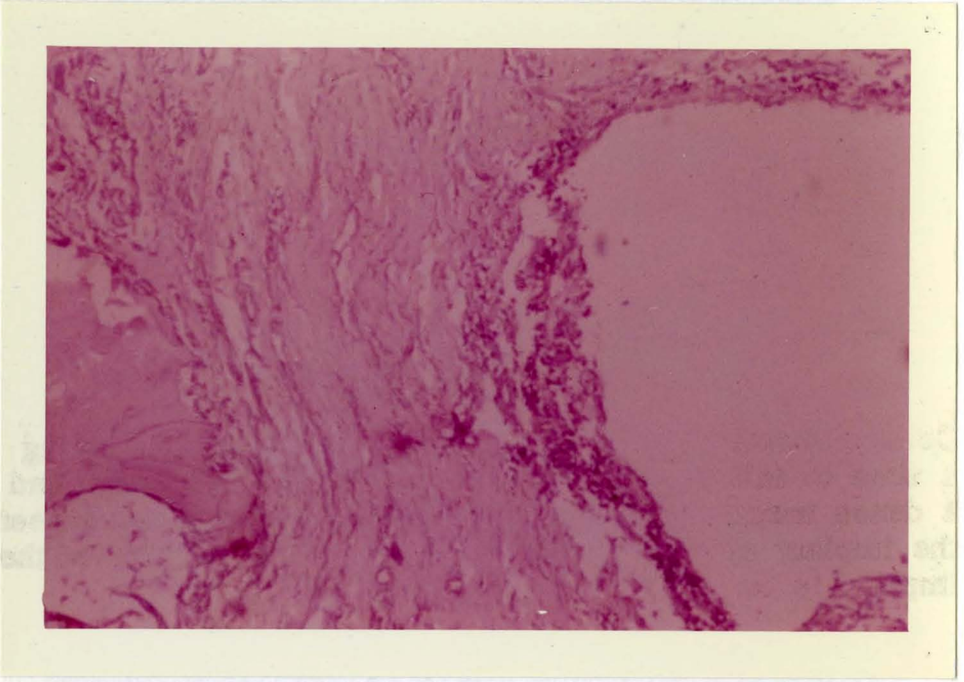

FIGURE 11

FIGURE 12

Color photomicrograph X 200 of one month specimen showing osteoclastic activity on the surface of bone which served as a base for the implant. H & E.

FIGURE 13

Color photomicrograph X 800 of Figure 12 showing osteoclasts. H & E.

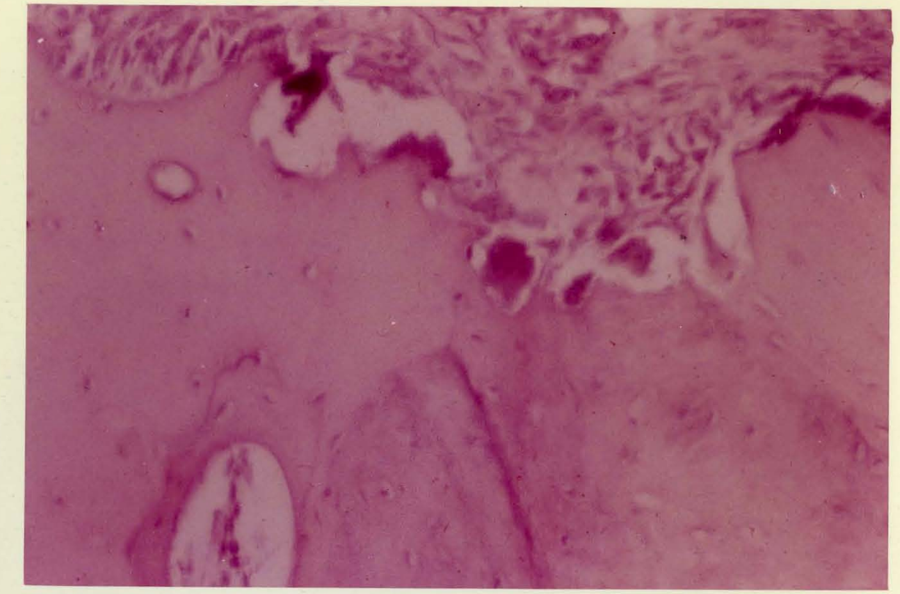

FIGURE 12

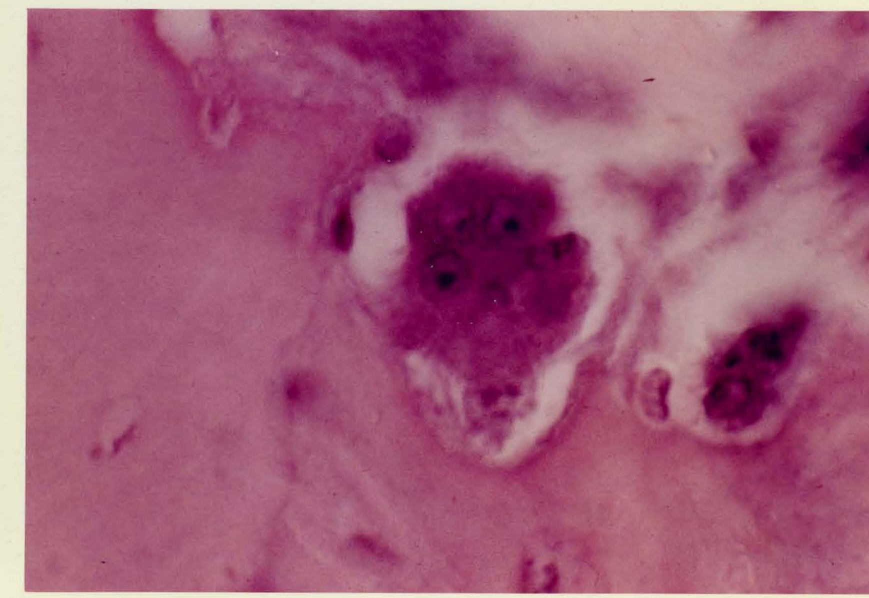

FIGURE 13

FIGURE 14

Color photomicrograph X 250 of one month specimen showing a layer of osteoblasts laying down new bone. A reversal line demarcating the old and new bone is evident and a slight amount of loose connective tissue is seen in the marrow space. H & E.

FIGURE 15

Color photomicrograph X 800 of Figure 14 showing: a) Osteoblasts, b) New bone, c) Reversal line and d) Old bone. The space in the upper right side is an artefact of the marrow cavity. H & E.

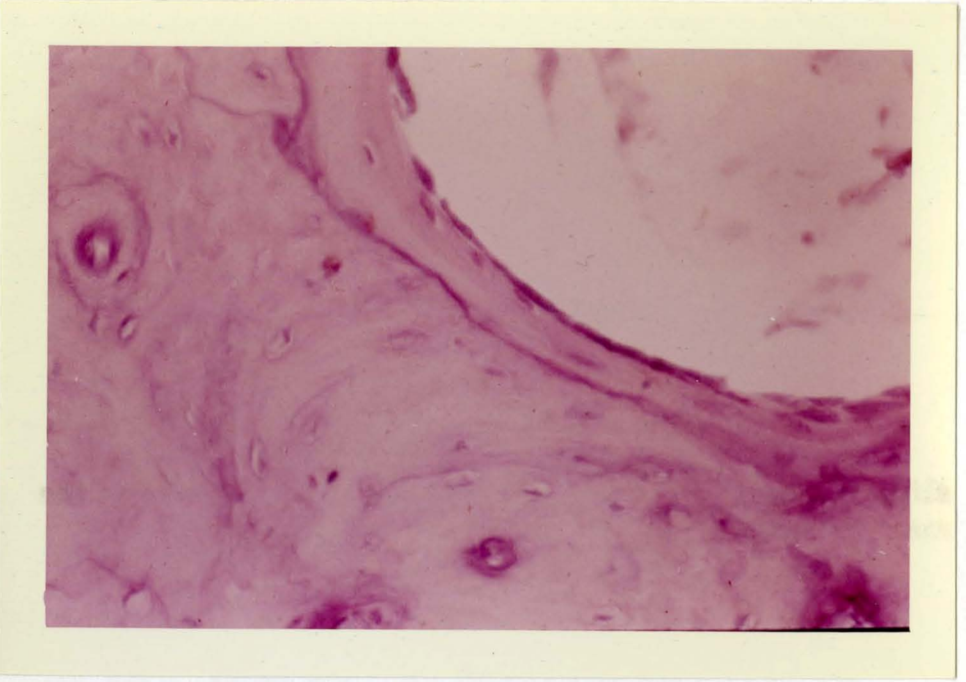

FIGURE 14

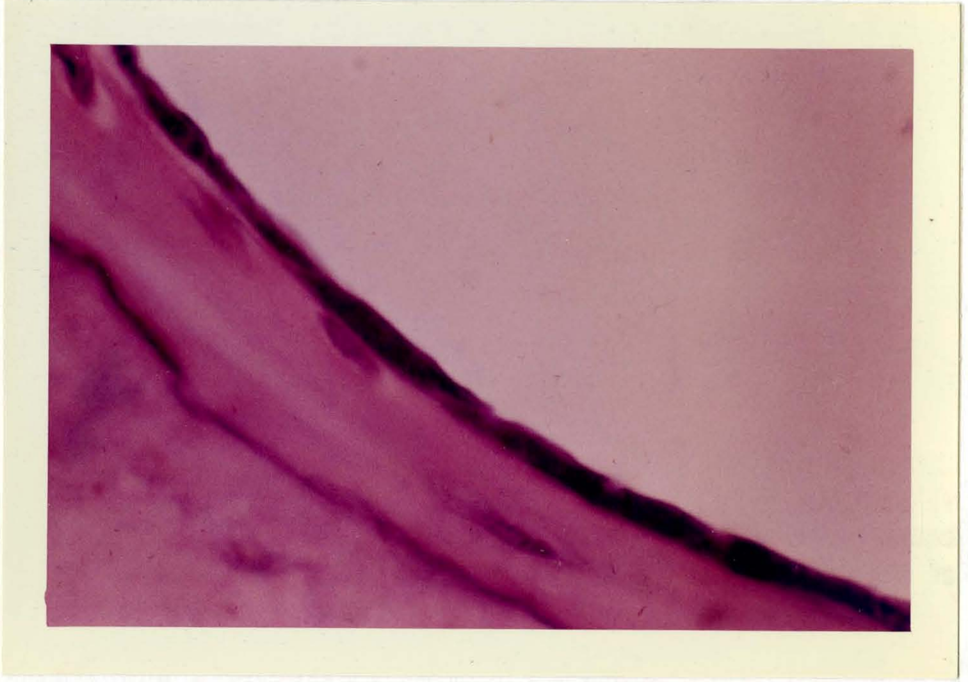

FIGURE 15

FIGURE 16

Color photomicrograph X 25 of three month specimen showing the prepared bony vault completely filled in by new bone. H & E.

FIGURE 17

Color photomicrograph X 100 of Figure 16 showing a dense cortical plate of bone in the area of the implant site. There is little or no osteoclastic or osteoblastic activity present.

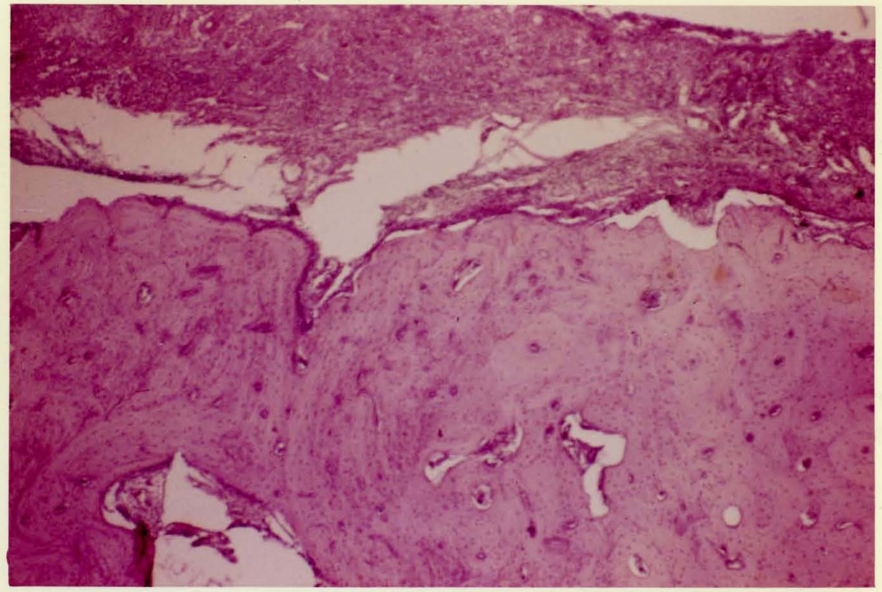

FIGURE 16

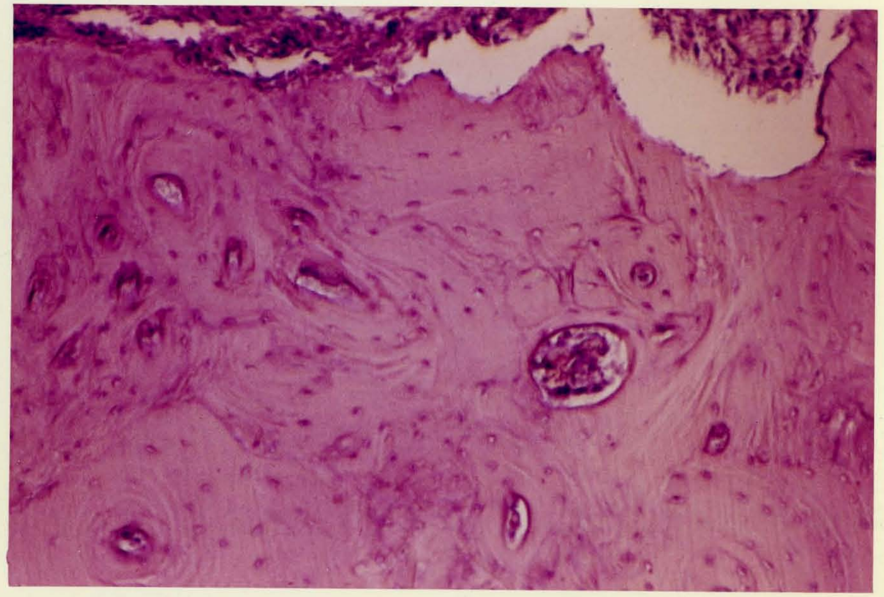

FIGURE 17

FIGURE 18

Radiograph of twenty-four hour specimen showing a distance of approximately 0.9 mm. between the two magnets. Bone surrounding the implant appears normal.

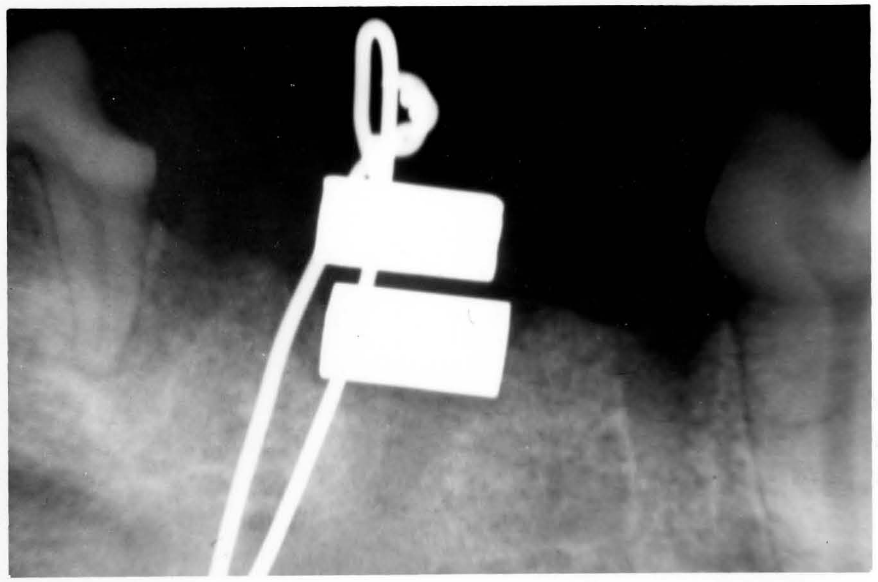

FIGURE 18

FIGURE 19

Radiograph of seventy-two hour specimen. The magnets are in contact at their anterior end and there is a distance of approximately 0.7 mm. between them at their posterior end.

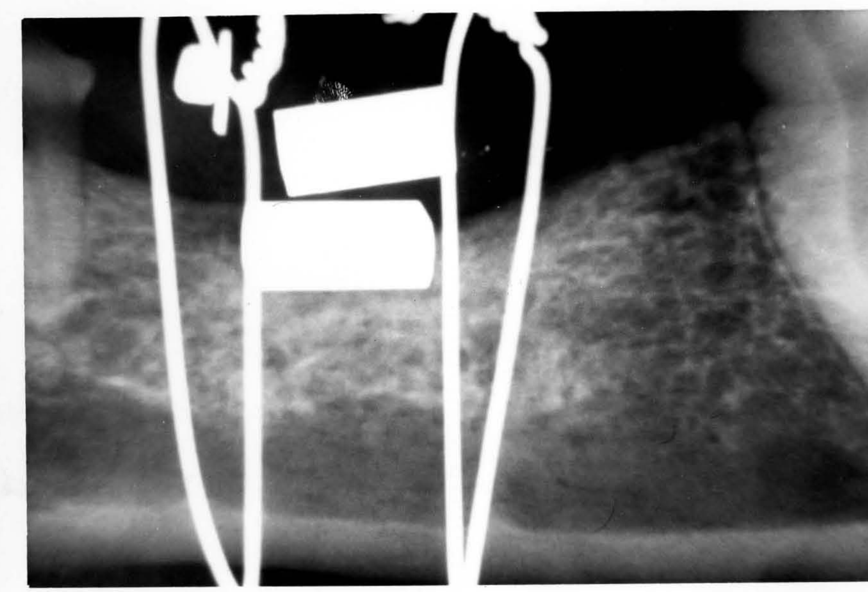

FIGURE 19

FIGURE 20

Radiograph of one month specimen taken the day the splint, containing the denture magnet, was inserted. The magnets are approximately 1.0 mm. apart at their centers.

FIGURE 21

Radiograph of one month specimen taken after the splint had been worn for one month. The magnets are in contact with each other and a slightly radiolucent area surrounds the implant which appears to be slightly above the alveolar crest.

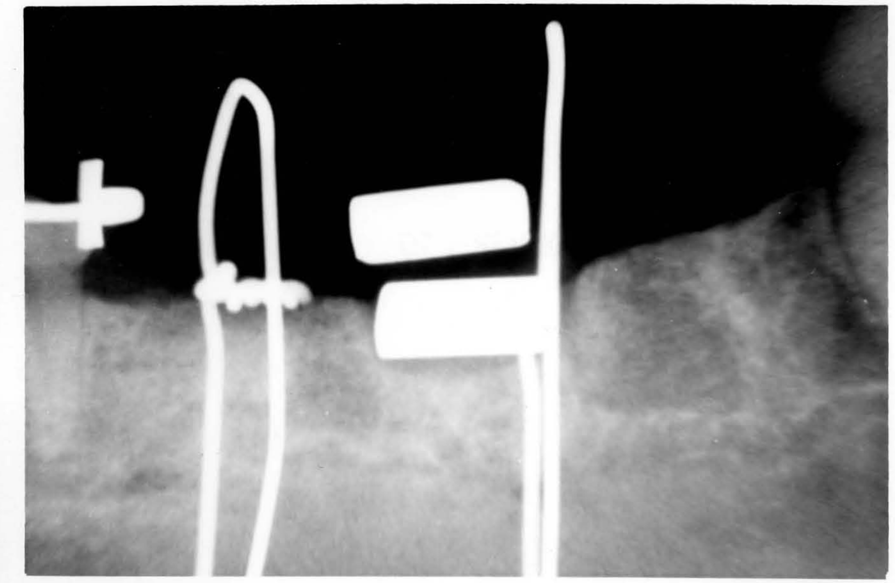

FIGURE 20

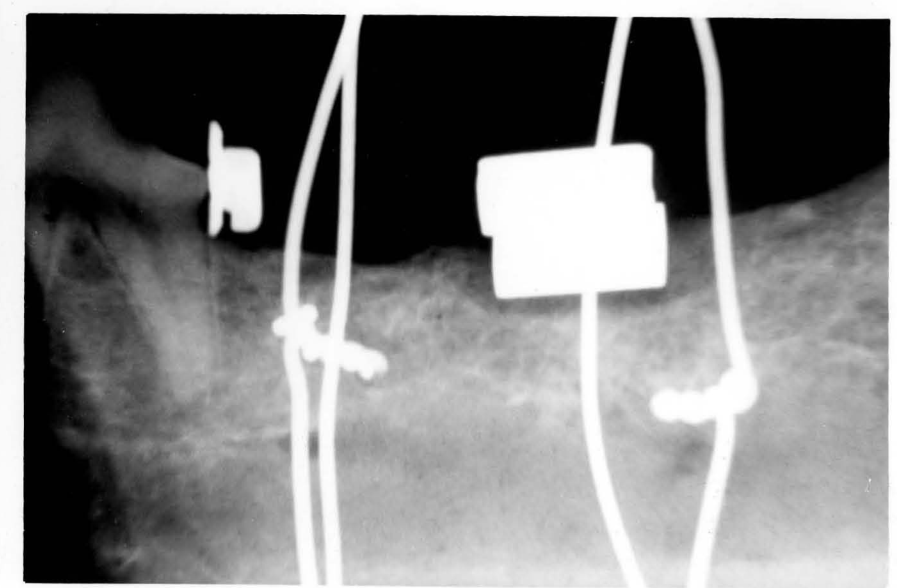

FIGURE 21

FIGURE 22

Radiograph of seventy-two hour control animal taken at the time of sacrifice. There is a distance of approximately 1.5 mm. between the two magnets.

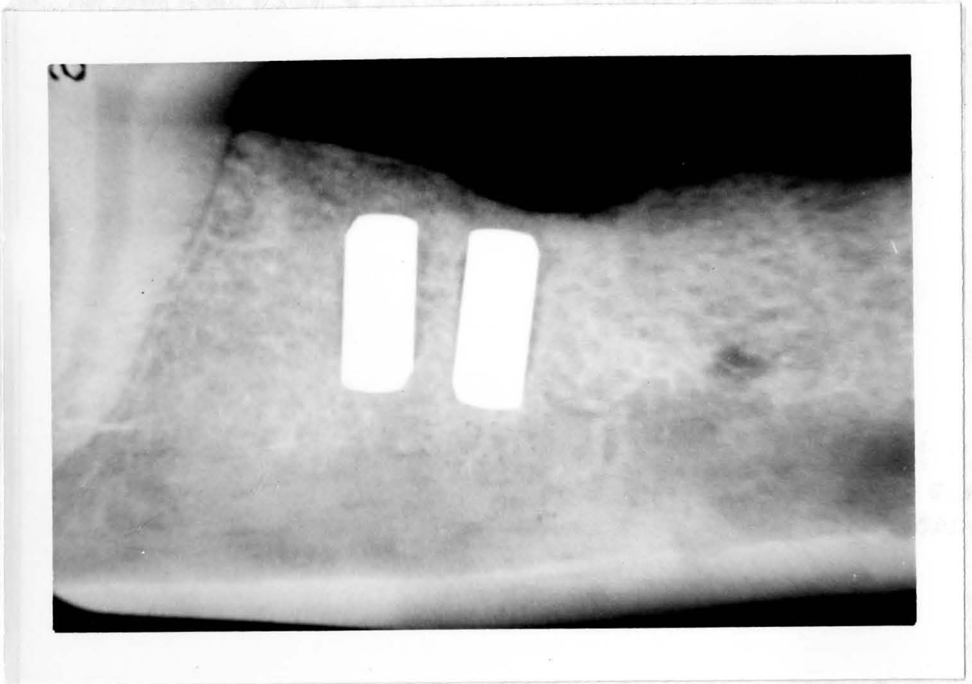

FIGURE 22

FIGURE 23

Radiograph of two month control animal taken at the time of sacrifice showing the two magnets in contact at their inferior ends. There is a distance of approximately 1.5 mm. between the magnets at their superior ends. There is a radiolucency between and around the inferior one-half of these magnets.

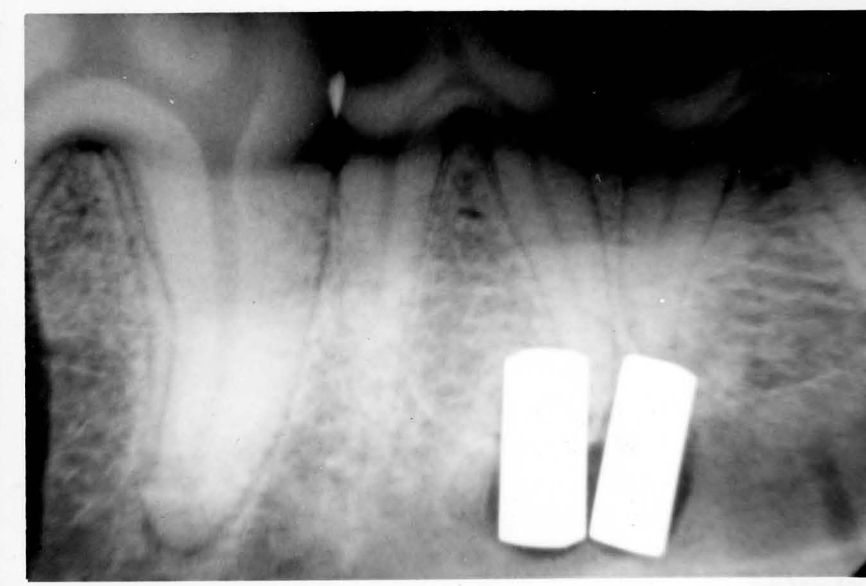

FIGURE 23

APPROVAL SHEET

The thesis submitted by Daniel D. Sanders 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 April 18, 1962

Nicholas C. Choukas, D.D.S., M.S.
Signature of Adviser

Nicholas C. Choukas, D.D.S., M.S.