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What is This?
Reaction of Bone and Mucosa to Implanted Magnets

PATRICK D. TOTO, NICHOLAS C. CHOUKAS, and DANIEL D. SANDERS*
Loyola University School of Dentistry, Chicago, Illinois

The objective of this report is to present the gross and histologic findings of the reaction of bone tissue and oral mucosa to magnetic implants when an attracting magnet of similar magnetic force is imbedded in an acrylic splint opposite the implant.

Behrman1 implanted a magnetized alloy of platinum-cobalt in the jaw of a human subject and placed a similar attracting magnet in the flange of a denture opposite the intrabony implant, to study the retention of the denture and the tissue reaction. After 8 months' observation there was no clinical evidence of deleterious effects; roentgenologically the bone filled the surgical defect and closely adapted to the magnet. Behrman implanted in the jaw of dogs 2 platinum-cobalt magnets, one coated with polytetrafluorethylene and the others left uncoated. After 10 weeks, the implants were removed and found to be unaffected. Histologic examination of the bone revealed that a thin fibrous capsule had formed around the implanted magnets.

Abati2 made detailed histologic examination of dog mandibles in which platinum-cobalt alloy magnets were implanted for periods ranging from 24 hours to 6 months. The healing adapted well to the implant, and, within 1 month, a thin fibrous capsule had formed around the implant. A comparison with non-magnetized platinum-cobalt alloy implanted in the mandible of dogs showed similar findings. It was concluded that the magnets were inert and did not affect the healing reaction of the bone; moreover, the implantation of such magnets may safely be employed to aid in the retention of dentures.

In order to test the effects of continuous magnetic attraction on the stability of an implanted magnet, a similar magnet was imbedded in an acrylic splint so fixed as to be positioned directly opposite the implanted magnet.

MATERIALS AND METHODS

Ten apparently healthy mongrel dogs were selected randomly from the general dog repository at the medical school. The dogs were anesthetized, using 1.5 cc. 1 per cent sodium pentobarbital per 3.5 kg. body weight. Surgical stage of anesthesia was reached in 15 minutes. A mucoperiosteal flap was reflected on the buccal surface of the mandible in the area of the second and third premolars. The premolars were surgically removed; the mucoperiosteal flap was repositioned and sutured to place. The jaw was permitted to heal for a period of 4 weeks.

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* In partial fulfilment for the degree of Master of Science, Loyola University School of Dentistry, Chicago, Illinois.
Another mucoperiosteal flap was prepared in the now healed edentulous premolar area of the mandible. Using a platinum (76.5 per cent)-cobalt (23.5 per cent) alloy magnet, $6.35 \times 3.55 \times 2.54$ mm., having a magnetic force of 3,283 oersteds as a template, a vault was prepared near the crest of the alveolar bone by means of carbide burs in a belt-driven handpiece and sharp chisels. The vault was curetted, and the sharp bony margins were smoothed with a bone file. The magnet was snugly placed in the bony vault with the aid of an orangewood stick (Fig. 1). The mucoperiosteal flap was repositioned and sutured to place; an alginate impression was taken of this area. The bone was permitted to heal for 4 weeks.

The animals were again anesthetized. A magnet was placed on the mucosa over the

![Fig. 1.—Reflected mucoperiosteal flap, the bony vault in the bone containing a snugly fitting platinum-cobalt alloy magnet.](image-url)

area of the implanted magnet in the dog’s mandible. This procedure allowed the applied magnet to orient its surface with that of the implanted magnet.

A plaster model prepared from the impression was used to construct a splint. A piece of wax of similar shape as the magnet was placed over the model, to create space as quick-cure acrylic was poured over the model. After setting, a “window” was cut into the buccal flange of the splint to communicate with the block of wax. After removing the wax, the splint was positioned over the magnet. The magnet could be viewed through the window; and when it was observed that there was no impingement of the splint on the magnet, quick-curing acrylic was used to fill the window space in the splint and to secure the magnet.

Two circumferential stainless-steel wires were threaded through the mucosa and around the inferior border of the mandible. The loose ends of the wires were knotted on the surface of the acrylic splint (Fig. 2). Care was taken to assure that the acrylic splint surface was not in occlusion with the maxillary premolars, in order to prevent
unnecessary trauma to the mucosa. The dogs were sacrificed at intervals of 24 and 72 hours; 1 and 2 weeks; 1, 2, and 3 months.

In 2 dogs, 2 each of the attracting magnets were implanted in the alveolar bone of the body of the mandible. They were positioned with 1.5 mm. of intervening cortical bone. One animal was sacrificed at 72 hours, the other at 2 months. This procedure was designed to determine the ability of attracting magnets to move through bone tissue. Roentgenograms were made at the time of splint placement and just prior to its removal.

The dogs were killed with a lethal dose of sodium pentobarbital. The splint was removed and the mucosa inspected. A segment of the mandible containing the implant was resected with the use of the Gigli saw. The specimens were fixed in 10 per cent formalin for 24 hours, when fresh fixative was added. The specimens were decalcified in formic acid–sodium citrate solution. When indicated, at this time, the magnet was gently teased from the bone. The specimen was dehydrated, imbedded in celloidin, and cut at 10 μ. The sections were stained with hematoxylin and eosin.

RESULTS

The splint was found securely fixed in all dogs. However, in the 3-month specimen, slight mobility could be determined by palpation. The mucosa was reddened around the circumferential wires in all specimens. Ulceration of such mucosa was noted in 3-month specimens. The mucosa covered by the splint appeared normal except for the depression left by the magnet.

The magnets implanted in the bone were found attached to the magnets in the splints, when removed, in all but the 24- and 72-hour specimens. Atrophy of the mucosa over one corner of the implanted magnet could be seen at 24 hours. At 72
hours, nearly half the implanted magnet was exposed by the atrophied oral mucosa.

The roentgenograms showed that there was approximately 1 mm of space between the surface of the implanted magnet and the surface of the magnet in the splints at the time of placement (Fig. 3). At 24 hours, this space was reduced to 0.9 mm. At 72 hours, the anterior surface was in contact (Fig. 4). All subsequent roentgenograms revealed that the magnets had come in complete surface contact (Fig. 5).

The circumferential wiring had produced resorption of the cortical bone on the inferior surface of the body of the mandible in the 2- and 3-month specimens as seen in the roentgenograms.

![Fig. 3.—Roentgenogram showing the position of the magnets at the time the splint was first applied.](image)

![Fig. 4.—Roentgenogram at 72 hours after the splint was applied. The magnets appeared to contact](image)
The 2 control animals, each with 2 attracting magnets implanted about 1.5 mm. apart, showed clinically normal healing. At 72 hours, there was little redness of the mucosa at the site of incision, while the 2-month specimen showed normal mucosa. Roentgenograms showed a distance between the magnets of 1.5 mm. in the 24-hour specimen (Fig. 6). However, in the 2-month specimen the magnets were in contact at their inferior borders (Fig. 7).

Histologic examination of the 24-hour specimen revealed the epithelium and lamina propria to be compressed between the 2 magnets. The epithelial cells showed pyknotic nuclei and hydropic degeneration. The collagenous fibers of the lamina propria were...
swollen and separated by a watery matrix. Few polymorphonuclear leukocytes and lymphocytes infiltrated the lamina propria. A thin fibrous capsule lined the bony vault previously occupied by the magnet. At the base of the vault, the fibrous capsule was denser than that on the opposing surfaces. Few osteoclasts were noted on the cortical and cancellous bony surface of the vault. Little loose connective tissue was observed in the marrow spaces.

At 72 hours, ulceration was seen in the epithelium. The cells showed pyknosis, chromatolysis, and hydropic degeneration. Polymorphonuclear leukocyte infiltration of the epithelium was evident. The collagenous fibers were swollen; lymphocyte and polymorphonuclear leukocytes infiltrated the lamina propria. The fibrous capsule about the space occupied by the implant appeared similar to that seen at 24 hours. Osteoclastic and osteoblastic activity was noted on the bony surface of the vault. An increase in loose connective tissue was seen in the marrow spaces. New capillaries and indifferent connective-tissue cells were increased as compared with the 24-hour specimen.

At 1 week, there was considerable ulceration of the epithelium. The bony vault appeared filled with loose and fibrous connective tissue (Fig. 8). Young fibroblasts with long, extended cytoplasmic processes were seen adjacent to collagen fibers (Fig. 9). Indifferent cells appeared wandering in the moderately vascular loose connective tissue. Lymphocytes and few scattered polymorphonuclear leukocytes were present in the connective tissue. Osteoclastic activity was still evident on the cut surface of the bony vault. The adjacent marrow spaces showed much loose connective tissue, fibroblasts, and osteoblasts opposing bone on the surface of the trabeculae.

At 2 weeks, stratified squamous epithelium, 2–4 layers thick, was found covering the connective tissue of the lamina propria. A large number of dilated capillaries, fibroblasts, lymphocytes, and few polymorphonuclear leukocytes were seen in the

![Fig. 7.—Roentgenogram of 2 implanted attracting magnets shown in contact at their inferior edges, at 2 months.](image-url)
lamina propria (Fig. 10). The lower portion of the mucoperiosteum showed mature collagenous fiber bundles and fibrocytes (Fig. 11). Osteoblasts were present on the surface of the bony vault; also reversal lines were seen.

At 1 month, the epithelium beneath the implant showed ulceration and a fibrinopurulent exudate. Also, a few bacterial plaques were seen. The lamina propria showed mature, dilated capillaries, plasma cells, lymphocytes, and a few polymorphonuclear

![Figure 8](image1.png)

**Fig. 8.**—The bony vault previously occupied by a magnet fitted with loose and fibrous connective tissue at 1 week. (Stain H. & E.; orig. mag. ×100.)

![Figure 9](image2.png)

**Fig. 9.**—Young fibroblasts, collagenous fibers, few polymorphonuclear leukocytes at 2 weeks. (Stain H. & E.; orig. mag. ×1000.)
leukocytes. The deeper portion of the lamina propria consisted of dense collagenous fibers, fibrocytes, and a few capillaries (Fig. 12). Osteoblastic activity on the surface of the bone vault was evident, as reversal lines were present. However, osteoclastic activity was still present on such bone surface (Fig. 13).

At 2 and 3 months, the findings were essentially the same. The epithelium showed ulceration, with only slight polymorphonuclear leukocytic infiltration. The lamina

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**Fig. 10.**—Thin atrophic layer of stratified squamous epithelium and vascular reparative tissue in the lamina propria beneath the magnet (space above) at 2 weeks. (Stain H. & E.; orig. mag. ×450.)

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**Fig. 11.**—Dense fibrous connective tissue at deeper layer of lamina propria filling the bony vault at 2 weeks. (Stain H. & E.; orig. mag. ×450.)
propria showed many dilated capillaries and perivascular edema. The collagenous fibers were separated by edema, and perivascular infiltration by plasma cells and lymphocytes. The dense, fibrous connective tissue deep in the lamina propria showed slight edema. This dense tissue filled the defect left by the implanted magnet. The bony vault had changed its architecture, being characterized by much new bone apposition. In fact, most of the bony vault was filled with new bone. The overlying dense

![Image](image_url)

**Fig. 12.**—Space outlining position of magnet surrounded by inflammatory cells. Dense fibrous connective tissue fills space previously occupied by the magnet at 1 month. (Stain H. & E.; orig. mag. ×100.)

![Image](image_url)

**Fig. 13.**—Osteoclastic resorption was evident on bony surface of vault. Reversal lines showing bone apposition has occurred at 1 month. (Stain H. & E.; orig. mag. ×450.)
fibrous connective tissue in contact with the bone showed few osteoblasts. The bone appeared normal and inactive (Figs. 14, 15).

Histologic examination of the 2 specimens containing 2 attracting magnets in the body of the mandible revealed, at 72 hours, bone resorption, many indifferent connective-tissue cells, new capillaries, and, in the adjacent marrow, osteoblastic activity, while the 2-month specimens showed osteoclastic resorption on the thin layer of bone

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FIG. 14.—Mucoperiosteum covering dense cortical bone filled in bony vault. Little reaction in the bone was seen. There still was evidence of inflammatory exudate in the mucoperiosteum at 3 months. (Stain H. & E.; orig. mag. X100.)

FIG. 15.—Dense cortical bone and many reversal lines at 3 months. (Stain H. & E.; orig. mag. X100.)
between the attracting surfaces of the implanted magnets. The magnets each had well developed dense fibrous capsules.

**DISCUSSION**

The implantation of a platinum-cobalt alloy magnet is well tolerated by cortical bone and the overlying mucoperiosteum. A dense fibrous capsule forms around the magnet, separating it from the bone. The capsule surface in contact with the bone serves as the reconstituted periosteum. These findings are in agreement with those of Abati. The platinum-cobalt alloy magnet must be considered as compatible with osseus and fibrous connective tissue.

The continuous attraction of an intrabony implanted magnet opposite a magnet imbedded in an acrylic splint results in a loss of the implanted magnet. The early observation of flattening and necrosis of epithelial cells in the mucoperiosteal flap directly above the implanted magnet indicated that the pressure exerted by the splint had injured such cells.

There was only slight reaction in the bony vault at 24 hours. However, proliferation of loose connective tissue in the adjacent marrow and the appearance of osteoclasts resorbing bone at 72 hours further indicated injury to the bone. Polymorphonuclear leukocytes were seen only superficially and may be related to the injury in the mucoperiosteal flap.

Pressure and even slight movement of the splint when the dogs were masticating compressed the mucoperiosteum. While such compression is known to induce a slight inflammatory reaction in the mucosa supported by bone, it induced both inflammation and atrophy of the mucosa when supported only by the magnet.

The loss of continuity of the mucoperiosteum created by ulceration was seen as early as 24 hours. Movement of the implanted magnet toward the magnet in the splint was clearly evident at 72 hours. The movement of the splint during mastication no doubt also caused movement of the implanted magnet, which contributed to additional injury of the mucoperiosteum and bone.

The presence of lymphocytes and plasma cells in the proliferating loose connective tissue indicated the presence of chronic irritation. Such reactions are commonly observed in cases of denture base irritation of the oral mucosa, as seen in human subjects. The splint fixed by circumferential wiring became loosened as a result of osteoclastic resorption of the cortex adjacent to the wires. It is probable that the wires were too tightly fixed over the splint, which contributed to pressure. The addition of masticatory forces to the fixed splint caused additional tension on the wires, causing resorption of the bone. The resulting mobility of the splint no doubt was a source of chronic irritation to the mucosa.

The attracting forces of the 2 magnets certainly must play a role in lifting the implanted magnet from its bony vault. The compression exerted by the 2 magnets upon the intervening mucoperiosteum combined with the mobility and pressure exerted by the fixed splint during mastication contributed to atrophy and inflammation.

The fibrous capsule on the superior aspect of the implant, which, in fact, was a continuation of the inner surface of the mucoperiosteum, was altered during inflammation. The dilatation of the capillaries, edema, and separation of collagenous fibers
was indicative of a physical change in the ground substance. In inflammation the ground substance shows a change from colloid-rich, water-poor to colloid-poor, water-rich phases. Such changes contributed to a loss in the dense collagenous fibers over the surface of the implant.

The collagenous fibers deep in the implant showed similar, but less dramatic, change. Only slight inflammatory exudate was ever noted in this area. This suggested that the magnet moved away orally from the deep part of the vault. Of considerable significance was the presence of osteoblastic activity and the reversal lines on the surface of the bony vault. While some osteoclastic activity was evident, there was a net gain in bone due to osteoblastic activity. The result was a filling-in of the bony vault with new bone.

The implantation of 2 attracting magnets in cortical bone with 1.5 mm. of intervening bone demonstrated that the force of the moving magnets stimulated osteoclastic resorption. The thin septum of bone between the 2 magnets showed osteoclastic resorption on both surfaces. As the bone was lost, the magnets moved into contact. A fibrous capsule was evident on the distal surfaces of the magnets. The mesial surfaces showed only loose connective tissue and osteoclasts. As implanted magnets have shown a well-developed capsule at 1 month, the failure of the attracting magnets to become completely encapsulated in 2 months must be attributed solely to the force exerted upon the bone by the moving magnets.

SUMMARY

Platinum-cobalt alloy magnets were implanted in the body of the mandible of 10 dogs. In 8 dogs, a similar magnet was implanted in an acrylic splint directly apposing the magnet implanted in a bony vault. Only the thickness of the mucoperiosteum separated the 2 magnets. The acrylic splint was fixed by circumferential wiring. Specimens were examined grossly and histologically at intervals ranging from 24 hours to 3 months. In 2 dogs, 2 attracting magnets were imbedded in bony vaults in the mandible, with 1.5 mm. of intervening cortical bone.

The mucous membrane under the splint showed evidence of chronic inflammation. The mucosa, intervening particularly between the magnet surfaces, showed inflammation, necrosis, and atrophy. Within 72 hours, the implanted magnet moved out of its vault to come in contact with the magnet in the splint. New bone formed on the surface of the bony vault, filling in the defect. Two attracting magnetic implants moved through bone to come into surface contact. Platinum-cobalt alloy magnets are well accepted by osseus and fibrous tissues. Continuous attraction of a magnet implanted in bone, with 1 inch secured in a splint fixed by circumferential wiring, results in chronic inflammation and atrophy of the mucosa directly intervening between the attracting magnets. Two attracting magnets implanted with only 1.5 mm. of intervening bone result in a loss of such bone by pressure exerted by the moving magnets.

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