Corrosion of silver cones in bone: a scanning electron microscope and microprobe analysis

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Sections of silver cones were implanted in tibial bone wounds in 36 Sprague-Dawley rats. Groups of six rats each were killed at monthly intervals, and the specimens were examined by scanning electron microscopy and by X-ray microanalysis. The silver cones had corroded rapidly, but they were well tolerated by the tissues. Elements of silver, chlorine, and sulfur were found in the tissues adjacent to the implants.

Silver cones have been a long-standing, acceptable endodontic obturating material. Within the tooth, this material can be considered an intracanal implant that is subject to surface corrosion by agents percolating from the coronal or apical seals. Whenever silver cones extend beyond the apical foramen, they can be considered an osseous implant and susceptible to degradation by the bone tissue fluids. Some metal implants may elicit an inflammatory response in the surrounding tissue that is proportional to the ions released by the corrosion process.[1] This electrolytic inflammatory reaction ranges from mild to severe and is characterized by pain, edema, and sinus tract formation.[2] The crucial level of concentration of ions to produce clinical changes is unknown.[3]

Previous studies of silver cones removed from human teeth disclosed that all the cones showed some physical change.[4,5] Those removed from treatment failures showed corrosion with pitting and cratering.[4] Less severe surface defects were seen in cones removed from successful cases.[5] When extensive corrosion was present, even the surface striations originally present on the cones were missing.

An electron probe analysis disclosed high sulfur peaks on the surfaces of corroded cones. Sulfur products result from surface corrosion, and have been demonstrated to be cytotoxic in tissue culture.[4]

The purpose of this study was to examine with the scanning electron microscope and X-ray microanalyzer the surface changes of silver cones in the osseous tissue of the rat.

Materials and methods

Size 100 silver cones* were cut into sections 2 mm long, and then autoclaved. Thirty-six Sprague-Dawley, white rats were anesthetized with sodium pentobarbital. Hair was removed from the inner hind legs, and an incision about 2 cm long was made through the skin and muscle to expose the heads of the tibias. With a no. 702 carbide bur at 2,000 to 3,000 rpm, a hole was made in each bone. One silver cone section was implanted in contact with the osseous wall in each tibia, and a suture was placed. A total of 72 implants was inserted.

At monthly intervals, for a period of six months, one group of six rats was killed with an overdose of anesthetic. The 72 tibias were removed and placed in 10% Formalin solution. The bones were then dehydrated in alcohol, air-dried, and glued to aluminum stubs. After being coated with carbon, the bones were examined and photographed in the scanning electron microscope.†

The bones were radiographed to locate the implant, fractured at the implant site, remounted, recoated with carbon, and examined with the scanning microscope and X-ray microanalyzer.‡ Channel windows were set to optimize counting of silver, sulfur, and chlorine peaks. Surfaces of the implant specimens were also examined in the same manner. Surface concentrations of sulfur and chlorine relative to silver were measured on the implants. Silver and sulfur were mapped on the microphotograph of

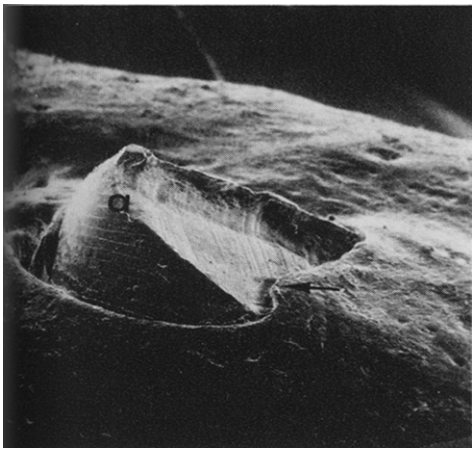


Fig 1—Scanning electron micrograph of two-month implant of silver cone material in rat tibia. Implant (a) *is partially covered by growth of new bone (arrow) {orig mag X82}.*

the bone surface by the elemental scan accessory of the X-ray microanalyzer.

Results

Of the 72 implants of silver cone material, 56 (78%) were present within the implant site at the various sampling periods of the study. The number of retained implants ranged from 8 to 12 at each monthly interval. The implants were tightly bound by fibrous connective tissue, and were either partially or completely covered by the new bone. This was especially true of the five- and six-month specimens. After two months, the borders of the implant site were healed, and new bone covered the implant periphery (Fig 1). At five months' duration, most of the implants were completely covered by new bone (Fig 2). After separation of the implant from some of the overlying bone, the new bone was in close apposition to the implant surface (Fig 3). The surface of the bone adjacent to the implant had areas of fibrous adhesion, representing the connective tissue capsule of the implant (Fig 4). Also present on all of the bone surfaces were areas bearing the surface characteristics of the implant material.

The surfaces of the one-month implants were partially covered by a rough layer with evidence of loose attachment at the edges (Fig 5). Under this outer layer, and in areas where the layer was not present, the implant surface appeared free of surface defects. The two-month implants were almost completely free of this rough, outer layer (Fig 6). The fine surface markings of the implant sites were from partially to completely covered by the circular markings of the implant (Fig 7, top). At higher magnification, the bone surface, in regions bearing the markings of the implant, appeared remarkably similar to the implant surface (Fig 7, bottom). This loosely adherent, outer surface of the silver implant was between 2μ and 3μ in thickness and closely followed the surface contours of the underlying implant (Fig 8).

Mapping of the implant site for silver and sulfur localized X-ray emission from these elements to the adherent surface material from the implant (Fig 9). Energy-dispersive X-ray analysis was performed on the implant surfaces and bone sites after implant removal. Silver and sulfur Kα X-ray peaks were emitted from both the implant and the bone surface (Fig 10). Sulfur and chlorine on the surface of the implant, relative to the amount of silver, increased to a maximum at three months after implantation. At the four- to six-month duration, those elements decreased to the concentration of the one-month implant (Fig 11).

Discussion

The results of the study indicate that the surface of a silver cone corrodes rapidly in bone. However, the implant appeared well tolerated by the tissue, which is in agreement with the findings of Hunter.[6] The silver cone was initially encapsulated by connective tissue, but was subsequently covered by bone. Sulfur and chlorine

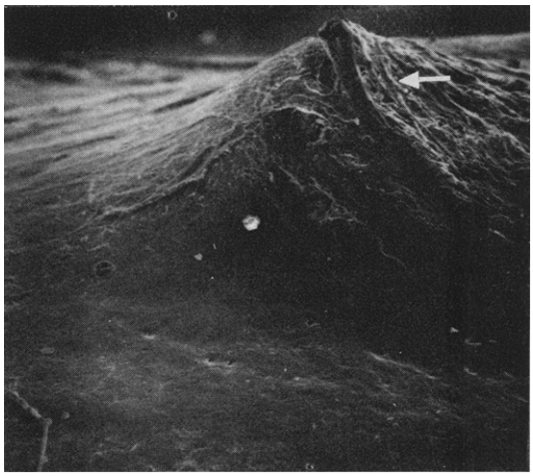


Fig 2—Scanning micrograph of tibial surface of implant site after five months. Outline of implant is seen beneath covering of bone (arrow) {orig mag X95}.

Fig 3—Scanning micrograph of implant of silver cone material in rat tibia after six months. Part of bone has been removed to show implant surface (a) *{orig mag X90}.*

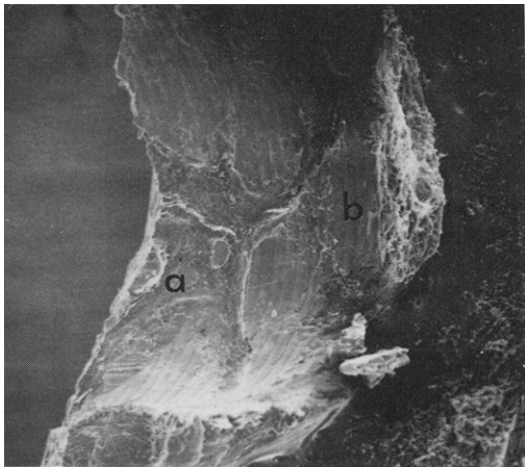


Fig 4—Scanning micrograph of bone surface in apposition to implant of silver cone material for six months. Areas of fibrous material are scattered on bone surface (a) *between regions bearing markings of the implant surface* (b) *{orig mag X90}.*

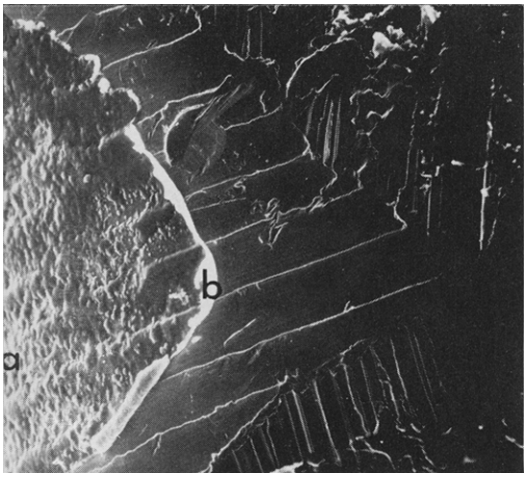
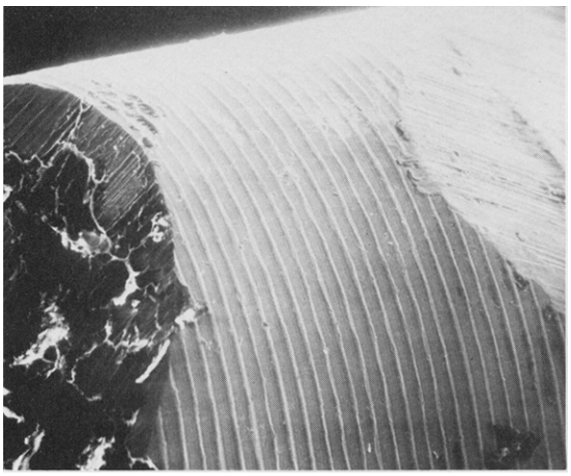


Fig 5—Scanning micrograph of silver implant after month. Rough surface of implant (a) *appears loosely adherent and curled at periphery* (b) *{orig mag X325}.*



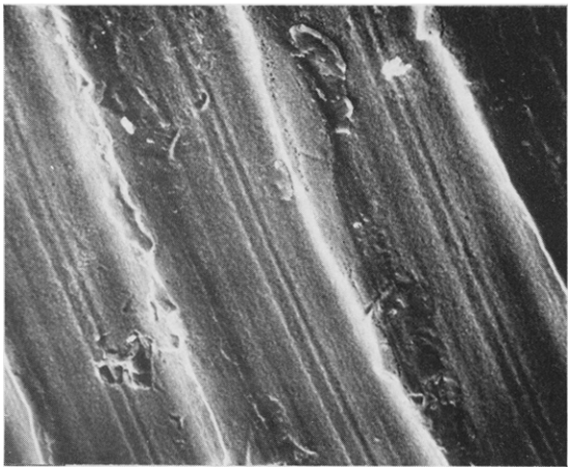
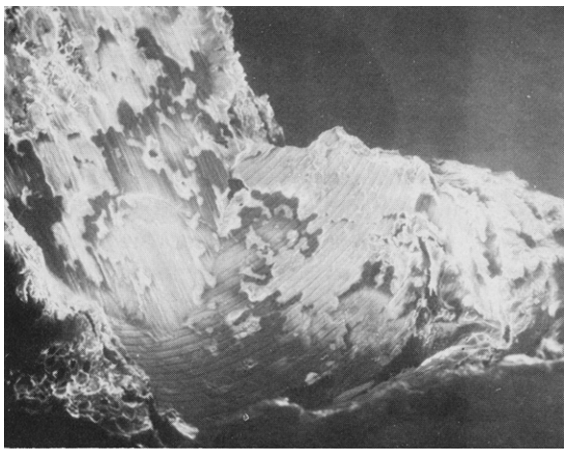


Fig 6—Scanning micrograph of silver implant after two months. Almost entire surface is free of adherent material (top, orig mag X120; bottom, orig mag X1200).



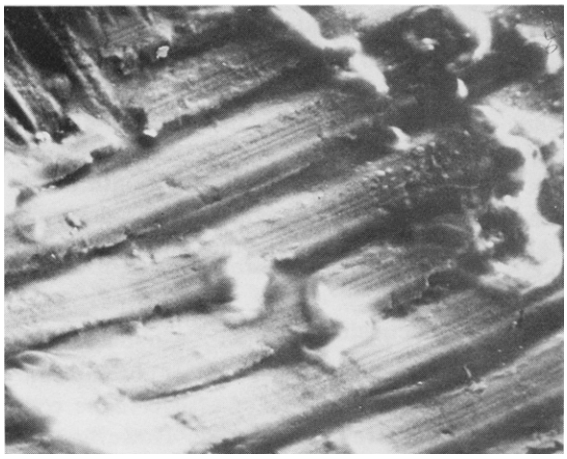


Fig 7—Scanning micrograph of implant site in bone after two months (top, orig mag X58; bottom, orig mag X600).

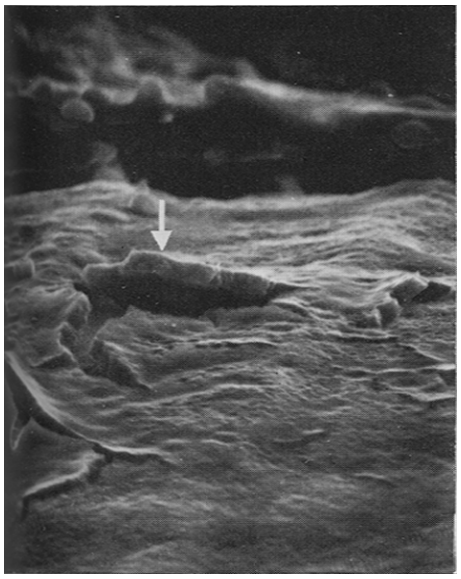


Fig 8—Scanning micrograph of surface of silver implant after six months. Outer layer of implant appears loosely adherent in region of dehydration crack (arrow) {orig mag X1800}.

were the only foreign elements observed on the implant surface; both were present in the loosely fixed, outer layer of the implant. Their maximum concentration, on the three-month implant, was probably a result of the loose attachment, and not an abrupt cessation of the corrosion. After three months, the outer surface of the implant was more firmly attached to the bone than to the implant. This outer layer separated from the implant when the implant was removed from the bone and the layer was left in the implant site. This is demonstrated by the metal surface markings, which contain silver and sulfur, and which are observed on the bone surface apposing the implant. In clinical situations necessitating removal of a silver point, this outermost layer will remain in the apical portion of the root canal or, more importantly, in the periapical area of the bone. In the long-term application of a silver

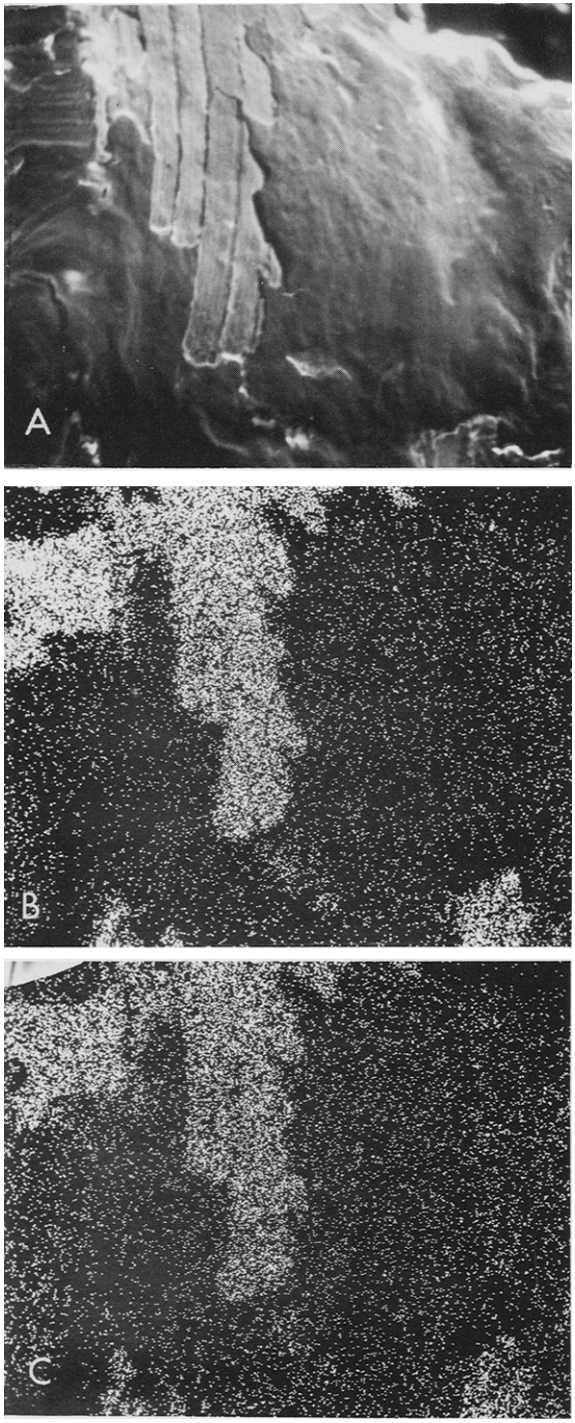


Fig 9—Scanning micrograph of implant surface material retained in two-month implant site (A, orig mag X290). Elemental mapping of silver in same area (B). Elemental mapping of sulfur in same area (C).

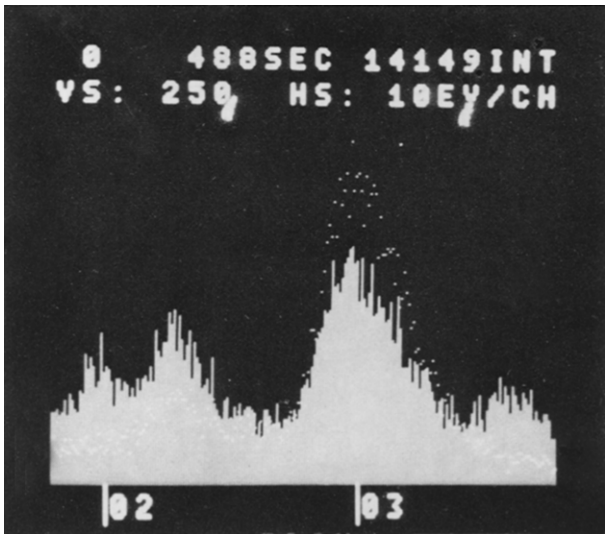


Fig 10—Electron microprobe spectra from a six-month implant specimen (dots) and from its corresponding base implant site (bars).

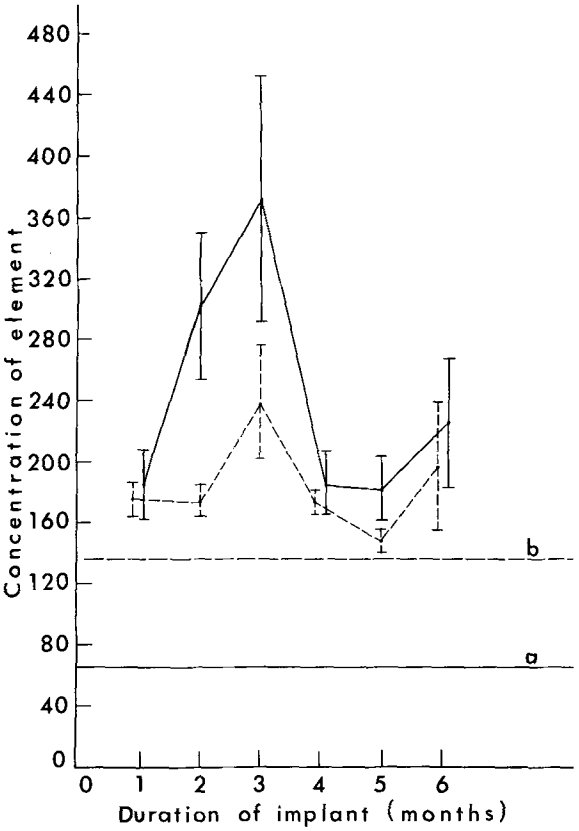


Fig 11—Graph of concentration of sulfur (a, *solid line) and chlorine* (b, *broken line) relative to silver on surfaces of silver implants from one to six months.*

cone, this outermost layer may constitute the greater portion of the apical mass of the implant. Whether this residual material has a toxic potential in clinical use should be more thoroughly investigated. We agree with Rud and Omnell[7] that the rapid deterioration of the silver endodontic cone occurs in the milieu of bone, and that this can only weaken the material. Our study supports the contention of Luks[8] that the use of silver cones as endodontic filling materials should be reevaluated.

Conclusion

Scanning electron microscopy disclosed that fragments of silver endodontic cones undergo rapid corrosion in the tibia of rats. However, the implants were well tolerated by both hard and soft tissues. Sulfur and chlorine were the only elements of the corrosion process detected by energy-dispersive X-ray analysis of the implant surface. The concentration of these elements was at its maximum on the implants removed after three months. The decrease in concentration thereafter was probably due to the retention of the surface layer of the implant by the newly formed bone. The surface of the implant was clearly seen in the implant site from scanning micrographs and elemental mapping. In a clinical situation when a silver endodontic cone must be removed from a root canal, this corrosion layer is probably left in both the root canal and in the periapical tissues. A reevaluation of the use of silver cone as a root canal filling material should be considered.

*Star Dental Mfg. Co., Inc., Conshohocken, Pa.

†Model 1000 Scanning Electron Microscope, Advanced Metals Research Corp., Burlington, Mass.

‡Energy Dispersive X-Ray Analyzer Model 707-A, EDAX Int., Prairie View, Ill.

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