EXPERIMENTAL OBSERVATIONS ON THE USE OF STAINLESS STEEL FOR CRANIOPLASTY
A COMPARISON WITH TANTALUM*

MICHAEL SCOTT, M.D., AND HENRY T. WYCIS, M.D.

Department of Neurosurgery, Temple University Hospital and Medical School, Philadelphia, Pennsylvania

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During the past war many articles were published on the use of tantalum for cranioplasty. To date the results have been satisfactory. However, the writers believed that it might be worth while to investigate the use of stainless steel in animal and human cranioplasties since the material has been used successfully for many years in various parts of the body. It is easily shaped and cut at the operating table, and its present cost is 1/290th of tantalum.

The use of stainless steel as suture material was first introduced by Babcock (1935), who showed that it evokes minimal tissue reaction as compared with catgut sutures.

The authors, as well as others, have found stainless steel wire very satisfactory for closure of laminectomies. Orthopedic surgeons have used it for bone plates and screws.

We can find no reference in literature concerning histological studies following the use of stainless steel plates in cranioplasties. Boldrey has used stainless steel wire mesh for the closure of small cranial defects. He placed a layer over the external table of the skull. No evidence of irritation of the meninges or brain was found, and fibrous and bony connective tissue practically welded the two wire-mesh layers into one firm plate. Chao, Humphreys and Penfield (1940) investigated the reaction following the use of stainless steel plates (as well as other metallic substances), in the subdural space for the prevention of meningoencephal adhesions. These authors make no mention of its use for cranioplasties.

The present communication deals with repair of cranial defects in dogs, using perforated, stainless steel plates.

The studies were carried out on three dogs, which were sacrificed at the end of six weeks, three months, and six months respectively.

Dog #1. Under intravenous nembutal a right parietofrontal craniotomy was performed. The dura was left open and the bone defect was repaired by an overlying stainless steel plate, $8 \times \frac{1}{2}$ cm. The temporal muscle was sutured over the plate with stainless steel wire sutures, and the skin closed. Wound healing was normal. After 6 weeks the animal was sacrificed. There was no fluid above or below the plate. After reflection of the temporal muscle

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† Analysis and thickness: The stainless steel plate was 0.015 inches in thickness. The stainless steel used had the following composition: carbon, 0.08–0.20%; manganese, 1.25% maximum; silicon, 0.75% maximum; sulfur and phosphorus, 0.03% maximum; chromium, 18–20%; and nickel, 8–10%.
the plate was found to be completely encapsulated by a thickened, smooth, glistening hyaline membrane.

**Microscopic.** Sections of this membrane did not reveal the presence of any inflammatory reaction. The membrane resembled a thickened dura. No photomicrographs were available for reproduction.

Dog #2. A bilateral trephine opening was made over both parietal areas. The dura was opened on the right and a small, perforated, stainless steel plate, 1½ cm. square, was placed beneath it in the subdural space and the dura closed with stainless steel wire. The muscle was closed with stainless steel wire. The dura was not opened on the left. A perforated stainless steel plate was anchored to the bone over the trephine opening by stainless steel wire. Healing was excellent and at no time were any collections of fluid noticed beneath the muscle or scalp. Three months later the animal was sacrificed by intravenous nembutal.

![Image](image_url)

**Fig. 1 (left).** Dog #2. The temporal muscle is reflected, showing the stainless steel plate surrounded by a thin, transparent capsule.

**Fig. 2 (right).** Dog #2. The outer capsular layer is reflected, exposing the underlying, shiny, stainless steel plate. No fluid was found above or below the plate.

**Autopsy.** Left trephine (plate sutured to external table around trephine opening). There was no serous collection beneath the scalp or temporal muscle. The undersurface of the muscle was adherent to a very thin, transparent capsule which covered the outer surface of the plate (Fig. 1). The capsule, approximately 1 mm. in thickness, was incised and reflected from the underlying shiny plate. The undersurface of this membrane was glistening (Fig. 2) and no fluid was found between it and the plate. The plate was completely encapsulated, and bands of firm tissue penetrating the perforations in it firmly united the outer and inner layer of the capsule. A section of this capsule, and overlying muscle, showed no inflammatory reaction (Fig. 3A). The plate was firmly anchored to the bone and upon elevation its undersurface was just as clean and shiny as the outer surface. There was no fluid beneath the plate. The bony defect was completely covered by glistening white tissue, the outermost layer of which was apparently the inner layer of capsule surrounding the plate. Sections of this tissue showed the absence of inflammatory reaction (Fig. 3B). The inner layer of the capsule was composed of a thickened layer of fibrous tissue consisting of numerous fibroblasts. The nuclei of the fibroblasts were arranged parallel to the surface of the capsule. The dura was flat, of normal color, and, although thickened, showed no inflammatory reaction (Fig. 3C). The bony edges of the trephine openings were smooth and showed no abnormal reaction.

**Right trephine** (subdural insertion of plate). The temporal muscle was reflected, exposing the dura. The dura was reflected laterally and a capsule was found adherent to its undersurface. The capsule was approximately 1 mm. thick and its undersurface was smooth and glistening, where it had been applied to the outer surface of the plate. Firm tissue had grown
Fig. 3. Dog #2. (A) The temporal muscle is adherent to the outer capsule, which resembles a thickened dura. This outer capsule was in contact with the outer surface of the stainless steel plate. (B) Inner layer of the capsule surrounding the stainless steel plate. (C) Thickened dura beneath the inner capsular layer. Note the absence of inflammatory reaction.
through the perforations in the plate and firmly united the outer and inner layers of the capsule. The plate was removed, revealing the inner layer of the capsule (Fig. 4). It was therefore apparent that the entire plate that was inserted into the subdural space was completely encapsulated. The inner layer of the capsule was thinner than the outer layer. The outer surface of the inner capsule was smooth and glistening and the undersurface of the inner capsule was attached to the underlying arachnoid by very fine, fibrinous adhesions which could be easily broken. Fig. 4 shows this layer separated from the arachnoid. The cortex showed an impression of the overlying plate. A block section was removed for study consisting of dura, both capsule layers, and underlying cerebral cortex (Fig. 5 A, B, C). The outer and inner layers resembled thickened dura. No inflammatory reaction was seen. The brain presented a normal appearance. The pia mater and the pia arachnoid were fused and showed slight increase in cellular content, but no inflammatory reaction was noted.

Dog #2. A small trephine opening was made over the right temporoparietal area and the dura was not opened. A small, perforated stainless steel plate, \( \frac{3}{4} \times \frac{3}{4} \) cm., was placed over the bony defect but was not anchored to the bone. The muscle layer was sutured over the plate. Healing was uneventful and the animal was sacrificed 6 months later. The incision healed well and no fluctuation was noted beneath the scalp. The temporal muscle was firmly adherent to the outer layer of the capsule, which, in turn, was firmly adherent by prolongations of tissue through the perforations in the plate to the inner layer of the capsule. There was no free fluid. Although the plate was not wired it was in good position and very firmly fixed by the surrounding tissue. The plate was shiny, and after removal the inner capsule was found to be smooth and glistening. The bony defect was completely healed in with fibrous tissue. Sections of the inner and outer layers of the capsule were studied histologically. Again the layer was found to resemble a thickened dura without evidence of any inflammatory reaction (Fig. 6 A, B).
Fig. 5. See opposite page for description.
Fig. 6. Dog #3. (A) The temporal muscle is adherent to the glistening outer capsular layer immediately above the stainless steel plate. (B) Inner capsular layer immediately below the stainless steel plate but above the intact dura. The tissue resembles a hypertrophied dura.

Fig. 5. Dog #2. Right-sided subdural insertion of stainless steel plate. (A) Outer capsular layer, which resembles thickened dura. Note the absence of inflammatory reaction. (B) Inner capsular layer adjacent to the pia arachnoid. The tissue resembles hypertrophied dura. (C) Cortex beneath the plate. The cortex approximates a normal appearance. The pia mater and pia arachnoid are fused and thickened.
COMMENT

The gross and microscopic studies made in three dogs showed that the stainless steel plates were completely encapsulated in every instance. There was no evidence of infiltration by polymorphonuclear leucocytes or round cells in any of the sections. There was no collection of serum above or below the plates. The reaction following the insertion of a stainless steel plate in the subdural space compared favorably with that reported by Pudenz and Odom following insertion of a tantalum plate in the subdural space.

Fig. 7. Repair of a defect in the lateral orbital wall in a human. The temporal muscle is reflected, exposing the perforated stainless steel plate.

We have used stainless steel plates in repair of cranial defects in three patients, but postoperatively the follow-up period is too short to warrant any conclusions. Fig. 7 shows a stainless steel perforated plate* inserted in a defect in the lateral orbital wall following decompression for malignant exophthalmos. The temporal muscle covered the perforated plate.†

* Stainless steel used in repair of human skulls was the same thickness as that used in the experimental work (0.015 inch).
† Dr. Rudolph Jaeger of Philadelphia, in his discussion of this paper, reported a case in which he had placed a huge stainless steel plate over the top of the skull following the removal of a meningioma. The procedure was done approximately 6 years ago. Reexamination of the patient a year ago (5 years later) showed excellent healing.
CONCLUSIONS

The reactions in dogs following insertion of stainless steel plates for cranioplasty and in the subdural space compare favorably with reports in literature concerning reactions to tantalum plates in similar locations. Since stainless steel plates are easily obtainable, can be cut, shaped, and molded at the operating table, and are approximately 1/290th the price of tantalum,* the authors believe that this material should be given a thorough clinical trial.

REFERENCES


* The price of a tantalum plate, 6×6×0.015 inches, is $29.40. The price of a stainless steel plate, 6×6×0.015 inches, is ten cents.