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SCREW FIXATION IN BONE OF GUINEA PIGS SENSITIZED TO NICKEL AND COBALT

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A screw was inserted transversely through the distal femora and proximal tibiae of guinea pigs sensitized to either Ni or Co. An equal number of nonsensitized animals were treated in the same way. The animals with Ni allergy received an ASIF stainless steel screw and the animals with Co allergy a Howmedica Vitallium screw. After 6 weeks no obvious differences were observed in the histological picture around the femur screws that could be ascribed to metal sensitivity. The mechanical strength of the bone adjacent to the tibial screws was tested by measuring maximum torque during continuous tightening of the screws at a rate of 2 revolutions/second. No significant differences in maximum torque resistance were found between sensitized and nonsensitized animals. The results indicate that sensitivity to Ni or Co does not compromise the mechanical fixation between metal and bone during the early period after the implantation.

Key words: allergy; alloy; bone; implant

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From clinical experience it has been found that orthopaedic implants can be used freely without prior patch testing of the patient with the constituents of the implants. As shown by Evans et al. (1974) sensitivity to cobalt and chrome can develop as a result of the extensive amounts of metal wear particles produced by McKee-Farrar metal-to-metal hip prostheses. However, Brown et al. (1977) found no support for the suggestion that sensitivity to metals was a cause of loosening. There are also reports on tissue reactions in patients with sensitivity to metals inserted for the fixation of fracture (Cramers & Lucht 1977). These reactions include signs of inflammation in the skin and subcutaneous tissues but little is known about the significance of inflammation in the deep structures.

In a rabbit model Merrit & Brown (1980) found that the histologic picture around the implant in animals sensitized to Ni was different from that of unsensitized animals. If an inflammatory reaction occurs, the implant would be expected to become loose. In order to investigate this we have developed a method for the mechanical testing of the strength of the bone around a metal implant. The method was used to elucidate if sensitivity to nickel affected the fixation of a stainless steel implant and if sensitivity to Co affected the fixation of a Vitallium implant.

MATERIAL AND METHODS

Adult female Guinea pigs were used. Sixteen animals were used for the Ni allergy study and seventeen were used for the Co allergy study. The animals were kept 3 to 5 in each cage and were fed a standard diet.

Sensitization methods

Ni contact sensitivity was induced according to the combined method of Polak & Turk (1968) using i.m.

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and i.c. injections and topical applications of $NiSO_46H_2O$ (Wahlberg 1976).

The allergy was maintained by intradermal injections and topical applications before the operations. To establish that the animals were adequately sensitized, challenge testing consisting of intradermal injection of 0.1 ml of $NiSO_46H_2O$ at concentrations of 0.5, 0.25, 0.125, 0.0625 and 0 percent in saline were were used (Wahlberg 1976).

Sensitivity to Co was accomplished according to the Guinea pig maximization test (Magnusson & Kligman 1969) using intradermal and topical administration of $CoCl_26H_2O$. The achieved sensitivity was maintained by intradermal and topical administration. For challenge, intradermal injections of $CoCl_26H_2O$ at concentrations of 0.2, 0.1, 0.05, 0.025 and 0 percent in saline were used (Wahlberg & Boman 1978).

Animals with the strongest test reactions were selected for the subsequent studies.

Surgical technique

The animals were anesthetized after 6 hours of fasting. Fentanyl – Fluanisone (Hypnorm, LEO) 1 ml/kg i.m. and Diazepam (Valium, Roche) 2.5 mg/kg i.p. resulted in surgical anesthesia within 10 min. Oxytetracycline (Terramycin, Pfizer) was given i.m. preoperatively at a dose of 50 mg/kg. Sterile instruments and draping were used. The operation area was shaved and soaked with 1 percent Chlorhexidine spirits. A skin incision was made on the medial side of the knee and the distal femur and the proximal tibia were approached. The knee joint was not opened. A transverse hole was made 5 mm proximally and 5 mm distally to the femorotibial joint space. The holes were tapped and stainless steel screws (AISI 316; ∅ 2.7 mm, length 10 mm; Synthes) or Vitallium screws (∅ 2.8 mm, length 11 mm; Howmedica) were inserted. A few days before sacrifice the animals were given another dose of oxytetracycline.

Laboratory technique

After killing the animals both hind legs were disarticulated through the hip and immediately put in plastic bags and refrigerated. The specimens were then cleaned of most of the soft tissues and stored in plastic bags at –20°C for varying periods. Without thawing the specimens, frontal X-rays were obtained (Figure 1).

After extraction of the screw the distal part of the femur on one side was decalcified, embedded in paraffin and sections stained with hematoxylin and eosin were prepared. The other femur was embedded in methyl methacrylate and microradiographs were obtained from 50–100 μ ground sections. Such sections were also used for UV microscopy.

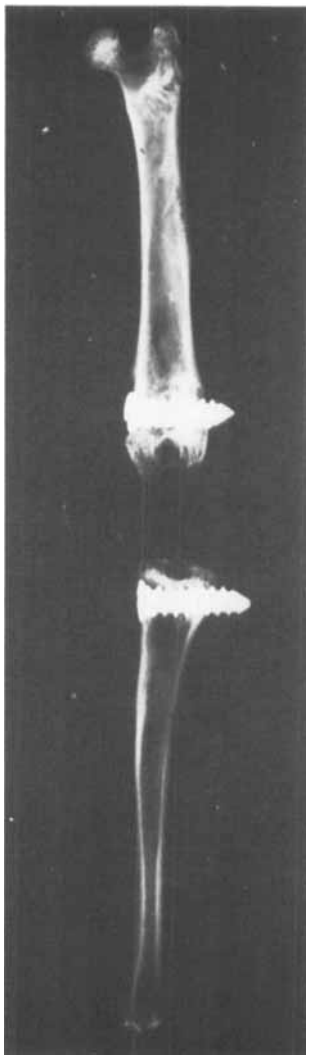

Figure 1. X-ray of dissected femur and tibia at 6 weeks after the insertion of the screws.

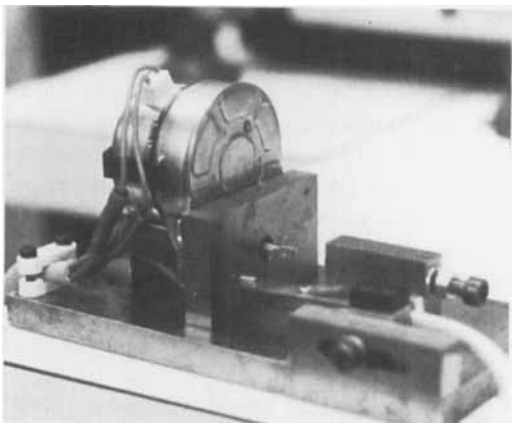

Figure 2. The device used for testing the fixation of the screws (see text).

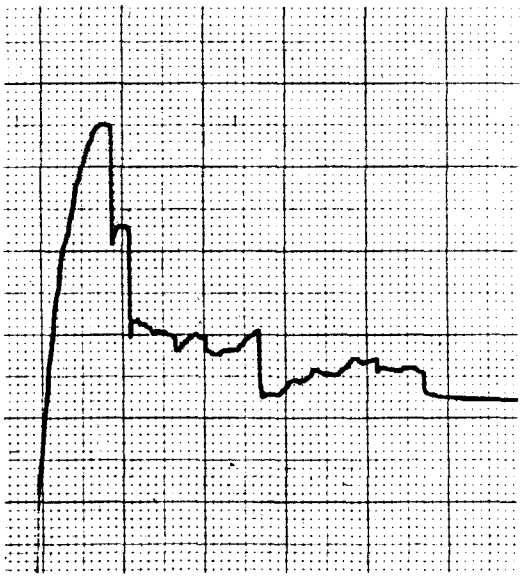

Figure 3. Example of printout showing the force taken up by the metal-bone transition.

The tibiae were separated from the femora and immediately after thawing tested for maximum torque resistance on tightening the screw. For this test a special apparatus was designed (Figure 2) where an electric asynchronous motor rotated the screw at a constant speed of 2 rev/s and the force at a distance of 3.5 cm from the screw was recorded. The tibia acted as a lever arm. The force was plotted on a diagram (Figure 3) as a function of time.

The tibiae were cut with a fine band saw 2.5 cm from the proximal end and the proximal part was then put in crucibles and ashed in 500° for 40 hours. The ash weight was obtained under standardized conditions 48 hours later.

RESULTS

No animal died during surgery but one death occurred in each of the control groups during the first postoperative week. Autophagia of the toes was seen particularly in the group sensitized to Co. All animals in the sensitized groups except one had positive skin tests before sacrifice, whereas all control animals were negative. The body-weight had increased in the Guinea pigs sensitized with Ni and their controls by about 20 percent due to their young age at the start of the experiment. The body-weight of the Co groups was essentially unchanged (Table 1).

Table 1. Body-weight (g) of Guinea pigs at the beginning and at the end of the experiment

		Preop body wt.	Final body wt.
Ni	Control	392± 6 (n=8)	551± 9 (n=7)
	Sensitized	496±20 (n=8)	605±25 (n=8)
Co	Control	661±30 (n=9)	669±15 (n=8)
	Sensitized	650±17 (n=8)	654±19 (n=8)

Values are means ± SE

All the tibial screws had been inserted in a very similar fashion with a mean of 0.95 mm (SE 0.01) inside the metaphysis. The part of the screw within the tibia at sacrifice did not vary between the groups. Still we found a mean variation in maximum torque resistance of the screws between the right and the left tibia of 29 percent and a much greater variation between different animals. However, no screw was loose and the variation occurred at a high level of fixation between the screw and bone, as can be seen from Table 2. This was true for screws in sensitized animals and even if the mean value was lower compared to the controls the screws were far from loose. The same conclusion can be drawn from the X-rays where resorption around the tibial screw could be seen only in two animals sensitive to Co.

There was no significant difference in the amount of bone ash of the proximal tibia between sensitized and control animals.

The histological evaluation revealed a zone of connective tissue around every implant. This

Table 2. Max force (N) exerted when continuously tightening the tibial screw at a constant speed

Ni	Controls	7.4±0.5
	Sensitized	6.7±0.5
Co	Controls	7.8±0.6
	Sensitized	6.6±0.6

Values are means ± SE

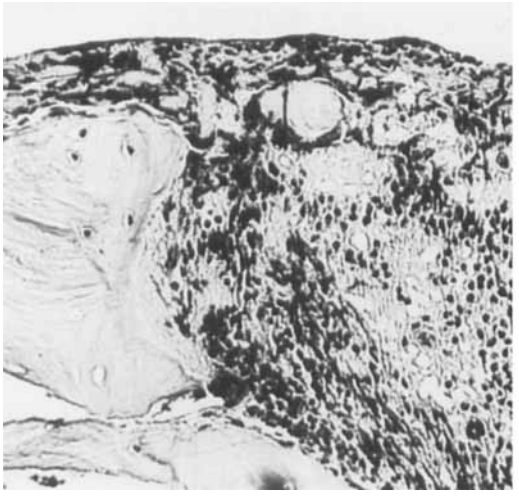

Figure 4. Cluster of round cells within the zone of connective tissue surrounding the implant in a Ni sensitive animal.

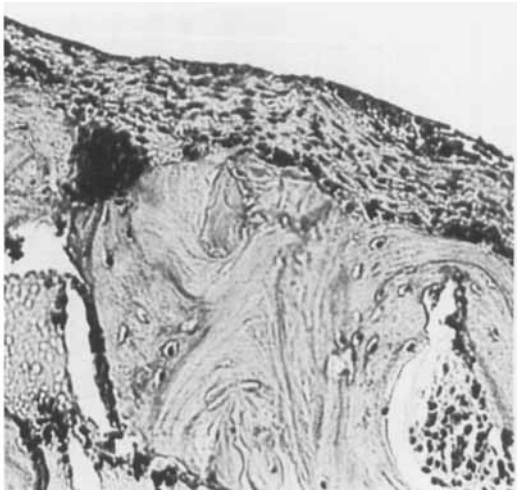

Figure 5. Inflammatory signs in the marrow around a Co implant.

layer was uniformly composed of elongated fibroblast-like cells. The Ni sensitive animals frequently had islands with densely packed marrow cells within the connective tissue around the stainless steel screw (Figure 4). This was not seen in the corresponding controls. A highly cellular bone marrow was especially seen around the Co implants which could indicate the presence of an inflammatory reaction (Figure 5). The histologic findings could not be graded objectively, and we found no difference in the number of eosinophilic cells or foreign body giant cells when comparing the controls and the sensitized animals.

UV microscopy revealed a high tetracycline uptake around each implant (Figure 6). In many cases the connective tissue layer seemed to invade the bone and to cut off the bone layer around the screw (Figure 7). This was more common in allergic animals. The microradiographs confirmed this finding.

DISCUSSION

The critical function of bone is its mechanical strength. In order to investigate bone function one must estimate not only the morphological picture but also the mechanical quality. Much has been written about the implications of allergy against metals used for implantation in bone and observations have been made on the morphology and also on clinical results. In patients, skin manifestations of the allergy have been the most commonly described complication. The most important question as to whether the bone metabolism and function will be disturbed remains to be answered.

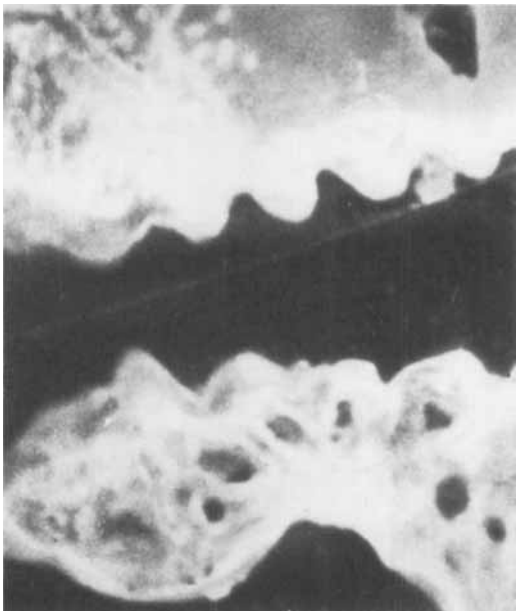

Figure 6. Tetracycline marked bone surrounding an implant.

Figure 7. Erosions of the bone formed around a screw.

The present experimental situation deals only with a short-term period after implantation and the results are thus more valid as regards material for osteosynthesis than for endoprostheses. The two most commonly used metals are chrome – cobalt – molybdenum alloys and stainless steel.

In the case of chrome – cobalt – molybdenum alloys, Co allergy was chosen for this study since Co is the major constituent and is often seen to cause contact sensitivity in dermatological practice. Ni allergy is very widespread in the population; it is a constituent of stainless steel and was therefore chosen as a model allergy for that study.

The present method of mechanical testing of the bone fixation of a screw has not been used before. Trader et al. (1979) tested the mechanical fixation of screws in the human radius by measuring the force required to push out the screw. They found a high correlation between that force and the bone mineral content. We regard the much smaller variation within the individual than between different individuals in this experiment as an indication of acceptable accuracy. The major source of errors is obviously to be found in variations in the implantation of the screw, which for the tibial screws seemed to be small.

The results showed that the mean force that could be applied to the screws in sensitized animals before they came loose was in the range of 10 percent less than in the control animals. Clearly the difference was not statistically significant but existed in both Co and Ni sensitized animals. It cannot be ascribed to osteopenia since the ash values did not differ between allergic and control animals. Neither was there a difference in the fraction of the screw which was within the bone. We therefore consider the small difference observed as an indication of the practical importance of metal allergy in disturbing the fixation of the metal in bone. This influence is, however, by far overshadowed by variations in the surgical procedure and by normal biological variations.

The differences in the histological picture are difficult to evaluate objectively. It is obvious that the bone formation occurring as a reparative process after implantation was quite undisturbed. This is indicated by the presence of living bone almost completely surrounding the screw in all cases. It is analogous to the process of fracture repair and is as such quite resistant to any disturbance. Inflammation around the implant may be associated with a weakening of the fixation. This could not be proven in this experiment but we believe that in the long run an existing allergy might lead to loosening, and this question will be further evaluated in a forthcoming paper.

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