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# SEGMENTAL REPLACEMENT OF THE FEMUR IN BABOONS WITH FIBER METAL IMPLANTS AND AUTOLOGOUS BONE GRAFTS OF DIFFERENT PARTICLE SIZE

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A study was made of bone ingrowth into fiber metal composite prostheses used to replace large segments of the femur in baboons. Bone grafts of two different types were used to cover the segment: chips of bone with large particle size and ground bone with a smaller particle size. The prosthetic segment was bridged by bone at 3 and 6 months in all cases irrespective of the structure of the transplant. In animals sacrificed at 6 months bone ingrowth occurred, with a marked difference between specimens with the two different grafts. In the ground bone specimens ingrowth occurred over the total surface area, and bone penetrated deep into the composite. With the chip grafts ingrowth was more irregular occurring only in some areas and it was always superficial. The difference is believed to be due to the improved contact between the fiber metal surface and the transplant. The lesser bulk of the ground transplant is advantageous when the soft tissue cover of the bone is thin.

*Key words:* bone transplantation; bone cement; prosthesis

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The transplantation of bone tissue is a common procedure in orthopedic and reconstructive surgery. The success of the transplant is related to its osteoconductive properties, its osteoproliferative properties, and its osteoinductive properties (Albrektsson 1971, Stringa 1957). The reaction of the bone cells to the grafted bone is also important. Both structural and functional qualities of bone grafts appear to influence their osteoconductive properties. Thus, the larger the surface area in relation to the total graft volume the better (Abbott et al. 1947, Albrektsson 1971, Albrektsson 1979, Burchardt & Enneking 1978, Burri & Wolter 1977, Burwell 1966, DeBrugn & Kabisch 1955, Deleu & Trueta 1965, Siffert 1955, Stringa 1957). The osteoproliferative and osteoinductive properties seem to be related also to structural qualities. Anderson (1961) studied the behavior of variously sized cancellous and cortical bone grafts in the anterior eye chamber of rats. Fragments below 1 mm diameter necrotized. Similar observations have also been made in intraskeletal situations by Keith (1934) and Siffert (1955).

In a previous study involving 38 adult baboons, 43 segments of a femur, tibia, or humerus were replaced with a sintered titanium fiber composite prosthesis (Andersson et al. 1978, Galante & Rostoker 1973). When autologous bone was grafted uninterrupted bone formed along the full length of the replacement segment. The bone ingrowth into the fiber metal segment was unpredictable, however, and usually occurred only in some areas. It was postulated that this could be due to the type of bone transplant used. Because of the thin iliac crest of the baboons, cancellous bone is not readily available. It was therefore necessary to use the cortical bone of the removed

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bone segment which was crushed into large fragments. Smaller size particles might have provided better graft-implant contact and additional bone ingrowth into the replacement segment.

The purpose of the present study was to compare bone ingrowth into a fiber metal composite when comminuted bone grafts of two different particle sizes were transplanted to bridge a diaphyseal defect.

## MATERIAL AND METHODS

Six adult female papio-papio baboons, weighing 10 to 13 kilograms were used. In all animals a 76 mm segment of both femurs was extraperiosteally resected, and replaced with a fiber metal segment of a rolling pin design that fitted into the bone defect (Figure 1). The core of the prosthesis, composed of Ti6Al4V alloy, consisted of a massive central segment, with projections of a smaller diameter from each end which were used as short intramedullary rods. The ends of the rods were manufactured into small caps. A fiber metal sleeve of unalloyed Titanium was sintered to the entire surface of the central segment and the intramedullary rods except for the tip of each rod where the cap was left uncovered.

All surgery was performed under general anesthesia using standard surgical techniques. Antibiotic prophylaxis with clindamycin was given routinely. Both legs were operated on in one session. A lateral approach was used, which permitted access to the femur without cutting through muscle. The resection was performed with a reciprocating saw cutting sharply through the periosteum and bone at right angles to the femur. Saline irrigation was maintained during the cutting procedure. Having removed the bone segment the prostheses were snapped into place. The intramedullary canals were not reamed but irrigated with saline. Care was taken to ensure a close mechanical fit between the prosthesis and the bone. Additional stability was obtained by the use of Ti6Al4V semitubular plates which were applied using a compression instrument and held with four stainless steel screws. Two screws were the maximum feasible number on each side of a prosthetic segment. The screws were secured to both cortices after pretapping of the drill holes. Autologous grafts were added on both sides using bone from the resected segment and from the iliac crest. On the left femur of each animal the bone was chipped into large pieces with a mallet and placed around the implant and over the contact areas between the prosthetic segment and the ends of the host bone. On the right side the chipped bone was further ground using a regular meat grinder to a particle size with a mean diameter of 6.8 mm (standard deviation 2.3 mm), and placed around the implant in a similar manner.

The animals were housed in cages with inside dimensions of 74 × 89 × 117 cm. Immediate weight-bearing was not restricted. Five to ten times a day the animals were stimulated to vigorous activity, such as jumping and swinging.

A single dose of 30 mg of oxytetracycline per kilogram of body weight was given intravenously 1 month

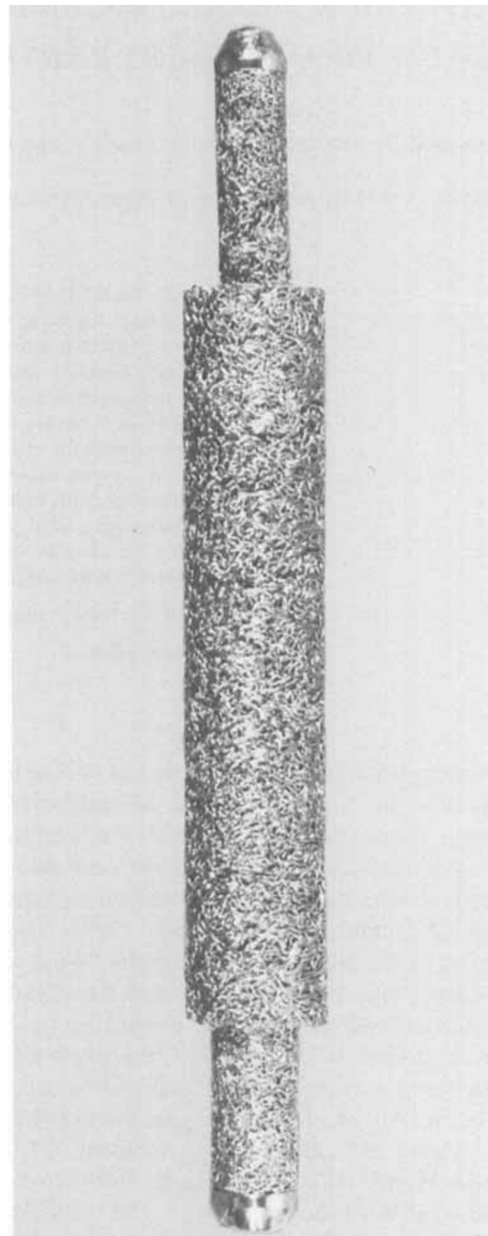

*Figure 1. The fiber metal implant was of a rolling pin design with a central replacement segment and two intramedullary projections.*

before death, and a single dose of 30 mg of chlortetracycline per kilogram of body weight was given 1 week before sacrifice. Two animals were sacrificed at 1 month, two at 3 months, and two at 6 months. Radiographs of each animal were taken monthly. After death of the animal, the entire implanted bone with surrounding soft tissue was removed. The plate was removed and the replacement segments were first evaluated macroscopically. Contact roentgenograms were then made of each specimen (anteroposterior, lateral, oblique views) before and after removal of the bone plate. The roentgenograms were rated for bone formation along the surface of the replacement segment and bone at the interfaces, and for the presence of any radiolucent areas between the implant and the adjacent bone.

Each specimen was then cut horizontally into ten sections (Figure 2). These sections were embedded undecalcified in polymethylmethacrylate, and then slices were cut with a diamond saw. These cuts were made perpendicular to the long axis of the femur in the areas of the intramedullary rods and the replacement segment, and parallel to the long axis across the interfaces where the replacement segment was in contact with the ends of the host bone. The slices were ground down to a thickness of 50–200 micrometers and stained with acid fuchsin. All sections were evaluated histologically for bone ingrowth. Separate evaluations were made of the area of the intramedullary rod, the interfaces between the replacement segment and the ends of the host bone, and the area of the replacement segment itself.

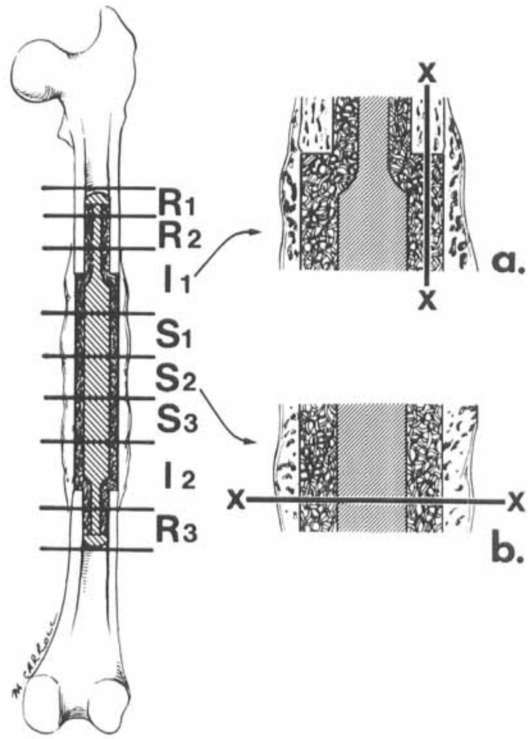


*Figure 2. The specimens were cut into sections. (R) denotes rod sections, (I) interface sections, and (S) segment sections.*
*Thin slices of the sections were cut parallel to the long axis across the interface area (a), perpendicular to the femur in the rod and segment area (b).*

## RESULTS

There were no operative or postoperative complications. All animals used their limbs on the first postoperative day and within 2 weeks their behavior was the same as it had been before surgery.

All prostheses, plates, and screws remained roentgenographically intact. A bone bridge had not developed along the replacement segment in any of the four limbs at one month. At 3 and 6 months uninterrupted bone formation was seen in all limbs. There were no obvious roentgenographic differences between the limbs in which ground bone was transplanted and those in which bone chips were used.

All plates were intact at autopsy. They were in close contact with the bone and replacement segment and firmly attached by the screws. No signs of gross loosening were found. In the animals sacrificed 1 month postoperatively callus formation was evident along the full length of the replacement segment. In the animals sacrificed at 3 and 6 months uninterrupted bone was found covering the segment, except under the plate where a thin layer of fibrous tissue was always present. A similar fibrous layer was found between the plate and the femoral cortex. No abnormal tissue reactions were noted, and the membrane was not considered suggestive of loosening. There was no gross evidence of bone resorption in the surrounding intact cortical bone.

Bone ingrowth into the surface of the rods, interfaces, and replacement segments occurred at only a few places in the animals sacrificed at 1 and 3 months. No difference was found between the animals with ground fragments, and those with large fragment transplants. At 6 months, on the other hand, bone ingrowth was found in all histological sections. A marked difference was observed in the amount of ingrowth between

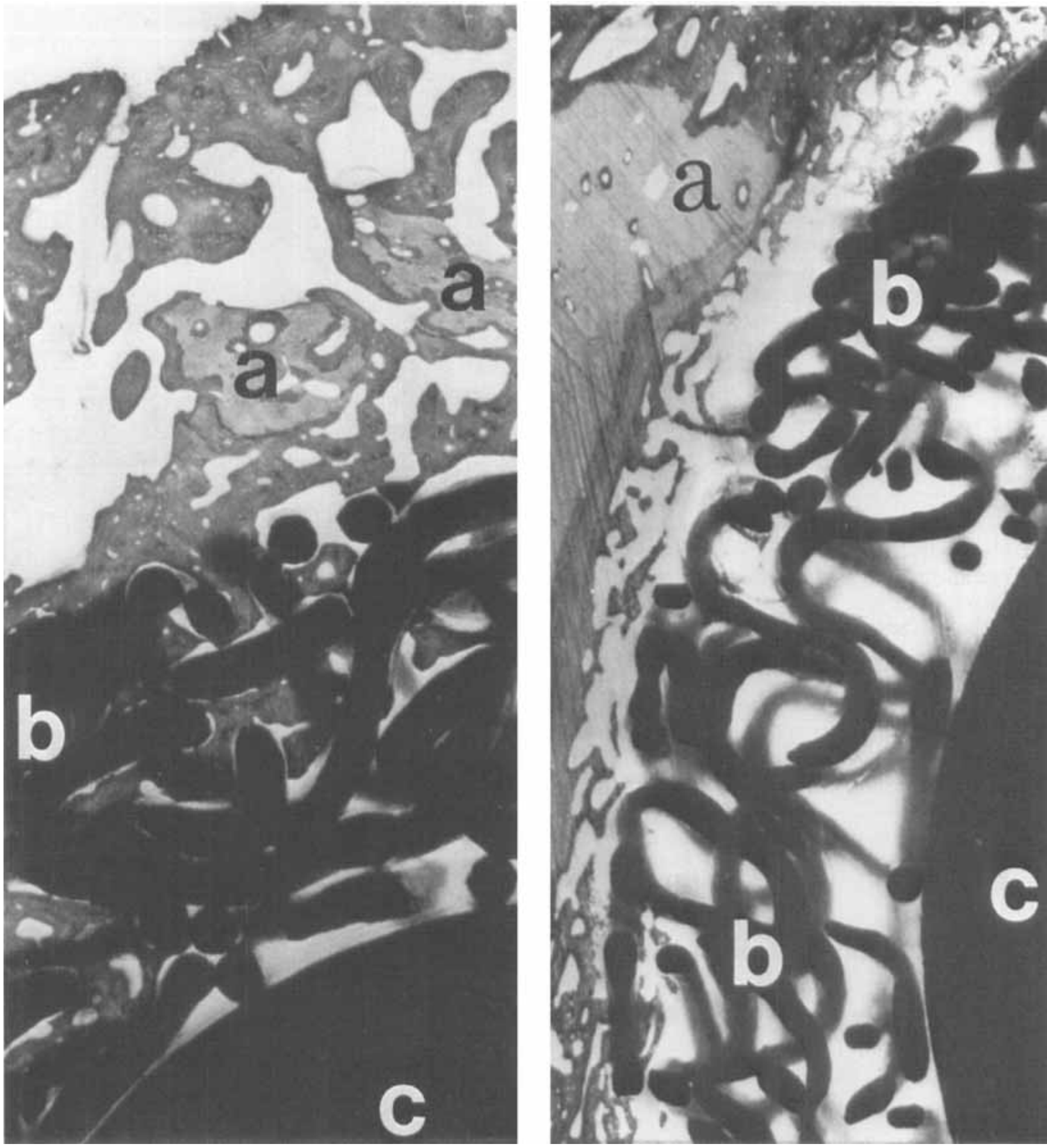


*Figure 3. Photomicrographs of histologic sections of 6-month specimens of baboon femurs.*
*A. Cross section of an area of a prosthetic segment with ground small particle graft, a) ground graft particles and new bone formation, b) the fiber metal coating with bone ingrowth, c) solid core of the segment. (×24)*

*B. Cross section of an area of a prosthetic segment with chipped large grafts, a) large chip graft, b) fiber metal coating, minimal bone ingrowth, c) solid metal core. (×18)*

specimens with the two different grafts. In the ground graft specimens ingrowth occurred over the total surface of the segment, and bone penetrated deep into the fiber composite (Figure 3). With the large fragment graft bone ingrowth was irregular occurring only in some areas, and it was always superficial. Fluorescence microscopy showed remodeling of the bone between the fibers where bone ingrowth occurred (Figures 4 and 5).

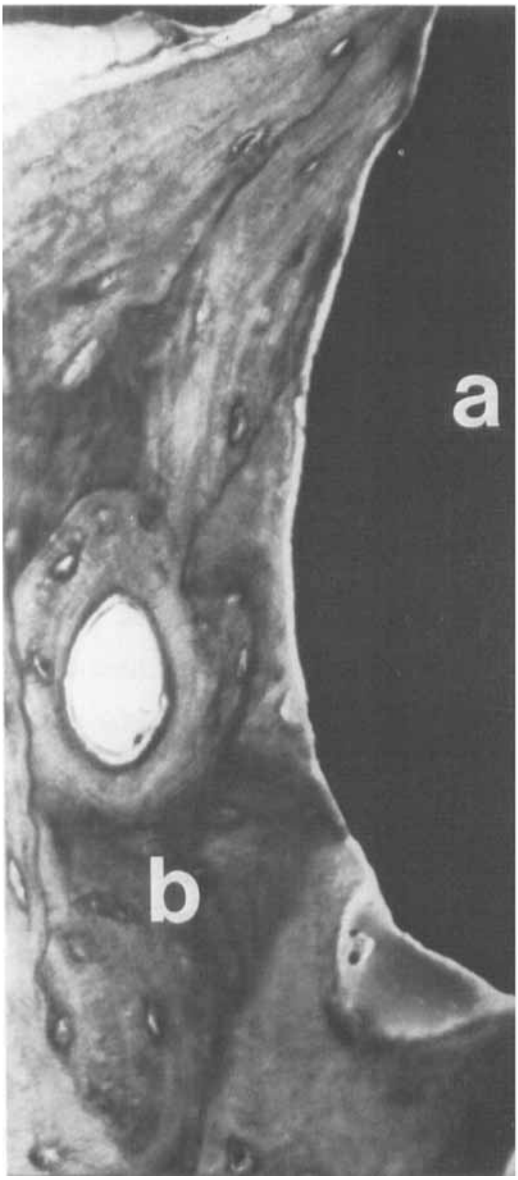


*Figure 4. Photomicrograph of bone ingrowth between fibers at 6 months, a) metal fiber, b) ingrowth bone (×370)*


*Figure 5. Fluorochrome double label at 6 months, a) metal fiber, b) labeled bone. (×160)*

## DISCUSSION

The study shows that diaphyseal defects can be successfully bridged by fragmented autologous bone grafts of different particle sizes. Ingrowth of bone was found only in a few sections at 1 and 3 months. At 6 months ingrowth was found in all sections. The ground bone with a smaller particle size was found to be superior with respect to bone ingrowth into the replacement segments. A more even ingrowth into the fiber metal occurred over a larger surface area with the ground bone than with the chipped bone transplants. This can probably be explained by the fact that intimate contact between ground bone graft and fiber metal was obtained over larger surface areas. Anderson et al. (1959) found that a heterogeneous bone paste with particle size varying from 0.3 to 0.7 mm was as rapidly vascularized as autogenous cancellous bone, while in heterogeneous cortical bone particles of 2.8 × 1 mm penetration of blood vessels was limited to 1 mm on the surface. The improved vascular penetration of the graft when it is in the form of a paste with a large surface area and an open texture may have been favorable but cannot be confirmed in the present experiment.

The previously mentioned studies by Keith (1934), Siffert (1955), and Anderson (1961) indicate that the critical size of the fragments is 1 mm in diameter. The particle size in this experiment was considerably greater and apparently did not influence the osteoproliferative and osteoinductive potentials of the graft.

The advantages of the ground bone chips over larger cortical pieces of bone are obvious in the handling and spreading of the graft over the surface area of a prosthesis of the type used in this experiment. The lesser bulk of the graft makes this type of grafting particularly useful in areas where the soft tissue covering the bone is thin.

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